NA-66-87

FABRICATION PLAN
FOR
FABRICATING
A

SIMULATED TITANIUM ALLOY Y-RING SEGMENT

FOR THE
S-1C FUEL TANK

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

NA-66-87

SERIAL NO 44

FABRICATION PLAN
FOR
FABRICATING
A
SIMULATED TITANIUM ALLOY Y-RING SEGMENT
FOR THE
S-1C FUEL TANK

PREPARED FOR
GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA 35812
CONTRACT NO. NAS8-20533

PREPARED BY

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PROJECT MANAGER

DATE 11 February 1966

NO. OF PAGES

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION
INTERNATIONAL AIRPORT • LOS ANGELES, CALIFORNIA 90009

FOREWORD

This fabrication plan describes the fabrication techniques established in Phase I and II of NASA Contract NAS8-20533 (Control No. 1-5-30-12546 1F) to fabricate two full-scale Y-Ring segments for the S-1C fuel tank, Figure 1. Also included in this report is an inspection and test evaluation program for the full-scale Y-Ring segments.

This contract is sponsored by the Manufacturing Engineering Laboratory (R-ME-1S) of the George C. Marshall Space Flight Center. The program is under the technical direction of Mr. Paul H. Schurer, Technical Program Manager. The Program Manager and Project Manager for North American Aviation, Inc., is Mr. Joseph Melill and Mr. Carl J. Muser, respectively. Others who participated in the program and the preparation of this report are: T. E. DeWitt Project Engineer; P. Miskulin and R. Brunken, Diffusion Bonding; R. Rohrberg and D. Harvey, Tool Design; L. Ecker, Machining; F. Koeller and J. Teeter, Forming; L. Fanelli, Leaching and Chemical Milling; J. Greenspan, Gary Keller, J. Riordan, Metallurgy; Wilson Kearns and K. McDonald, Manufacturing; F. Janney, C. Phillips and J. Russell, Quality Control; and Al Schanhaar, Industrial Engineering.

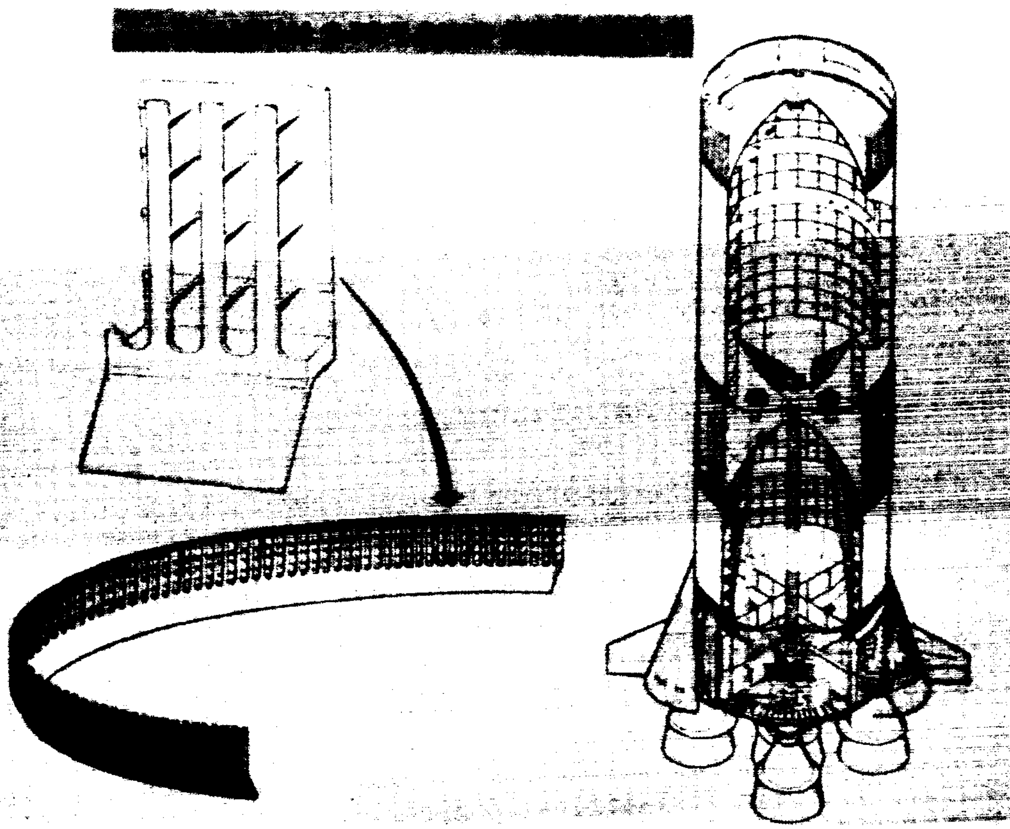

FIGURE 1.

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FABRICATION PLAN

TECHNICAL PLAN

It is the purpose of this program to perform Research and Development for the Fabrication of a Titanium Y-Ring Segment. The final requirement will be the fabrication and evaluation of two (2) Full-Scale Titanium Y-Ring Segments. These segments will be fabricated to NAA Drawing No. 2623-005 (Figure 2), and will be nondestructively tested; with one complete segment being shipped to MSFC and one segment being destructively evaluated by NAA.

FABRICATION SEQUENCE

It is planned to utilize processing techniques for diffusion bonding, machining, hot forming, thermal treatment, steel tooling removal (leaching), and surface clean-up (chem-milling) developed during Phases I and II of the program(reported in NA-66-104)for the fabrication of two (2) Full-Scale Y-Ring Segments in Phase III. Figure (3) is a fabrication sequence flow chart showing the major fabrication operations planned for the full-scale segments. The fabrication operations are outlined below and described in succeeding paragraphs.

1. Production Planning
2. Material Procurement
3. Pack Lay-Up and Seal
4. Roll Diffusion Bond
5. Yoke and Cover Plate Removal
6. Inspection
7. Machine Flange Radii
8. Hot Contour and Duplex Anneal
9. Machine Pockets
10. Steel Tooling Removal (Leaching)
11. Surface Clean-Up (Chem-Milling)
12. Inspection and Evaluation
13. Shipment to MSFC

PRODUCTION PLANNING

All parts and assemblies will be individually planned to establish the use of tools, equipment, sequence and schedule of manufacturing and inspection operations required to complete them in the most economical manner. The production order issued by planning is the authorizing document for all work performed by manufacturing. This order is produced in sets. Copies are used to set up an EDP record for reporting and control (SCAN entry), delete material from inventory, control the location and movement of parts and material, form a permanent inspection record, and other special requirements dictated by program requirements. Estimated hours and schedule are included on each production order. See Figure (4) for a typical production order.

MATERIAL PROCUREMENT

Orders have been placed for the procurement of all the materials required for the fabrication of the two (2) Full-Scale Y-Ring Segments. The 8Al-1Mo-1V titanium details have been ordered from Reactive Metals with a schedule delivery date of 25 February 1966. This material is being purchased per NAA/LAD Process Specification LB0170-177, and after receival,

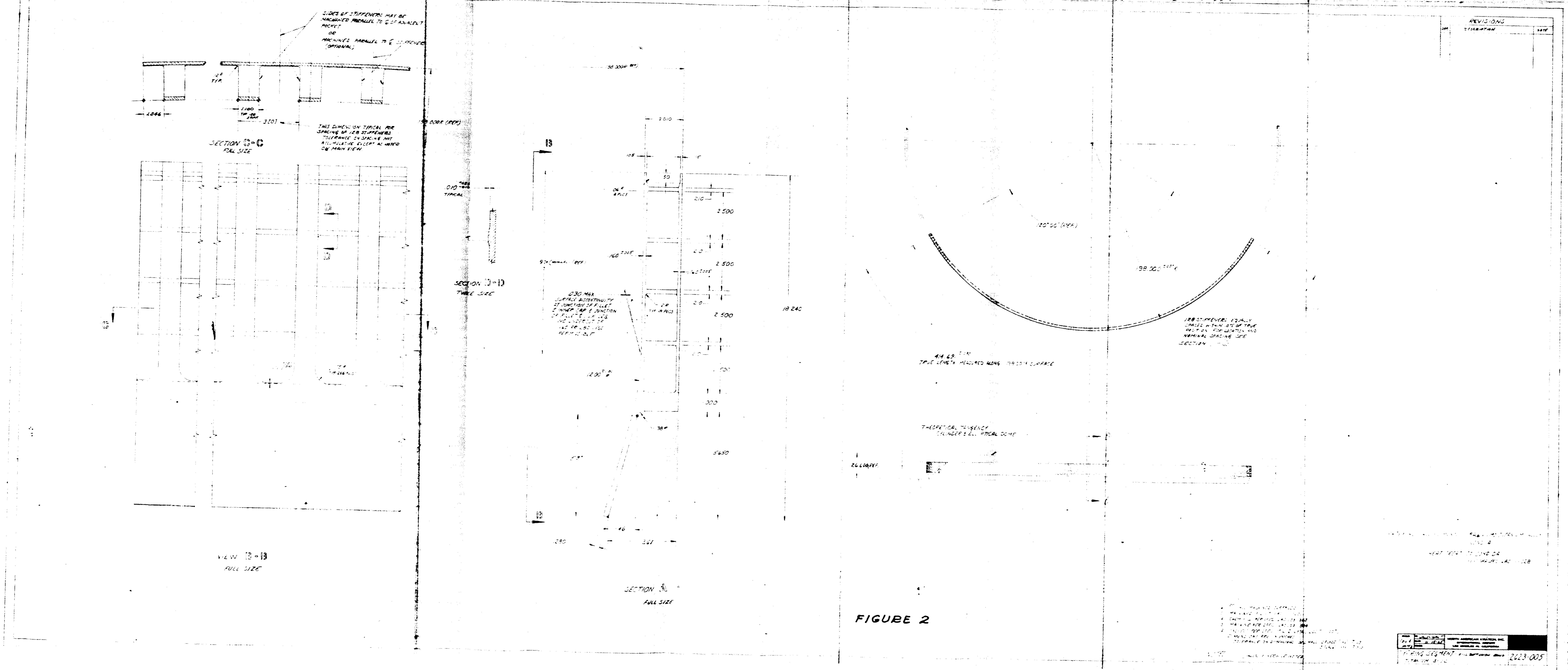

SIDES OF STIFFENERS MAY BE MACHINED PARALLEL TO ⊄ OF ADJACENT POCKET OR MACHINED PARALLEL TO ⊄ STIFFENER (OPTIONAL)
THIS DIMENSION TYPICAL FOR SPACING OF 128 STIFFENERS TOLERANCE ON SPACING NOT ACCUMULATIVE EXCEPT AS NOTED ON MAIN VIEW
SECTION C-C
FULL SIZE
VIEW B-B
FULL SIZE
SECTION D-D
TWICE SIZE
SECTION A
FULL SIZE
120°00' (REF)
128 STIFFENERS EQUALLY SPACED WITHIN .015 OF TRUE POSITION. FOR LOCATION AND NOMINAL SPACING SEE SECTION
TRUE LENGTH MEASURED ALONG SURFACE
THEORETICAL TANGENCY CYLINDER & ELLIPTICAL DOME
REVISIONS
NORTH AMERICAN AVIATION, INC.

FIGURE 2

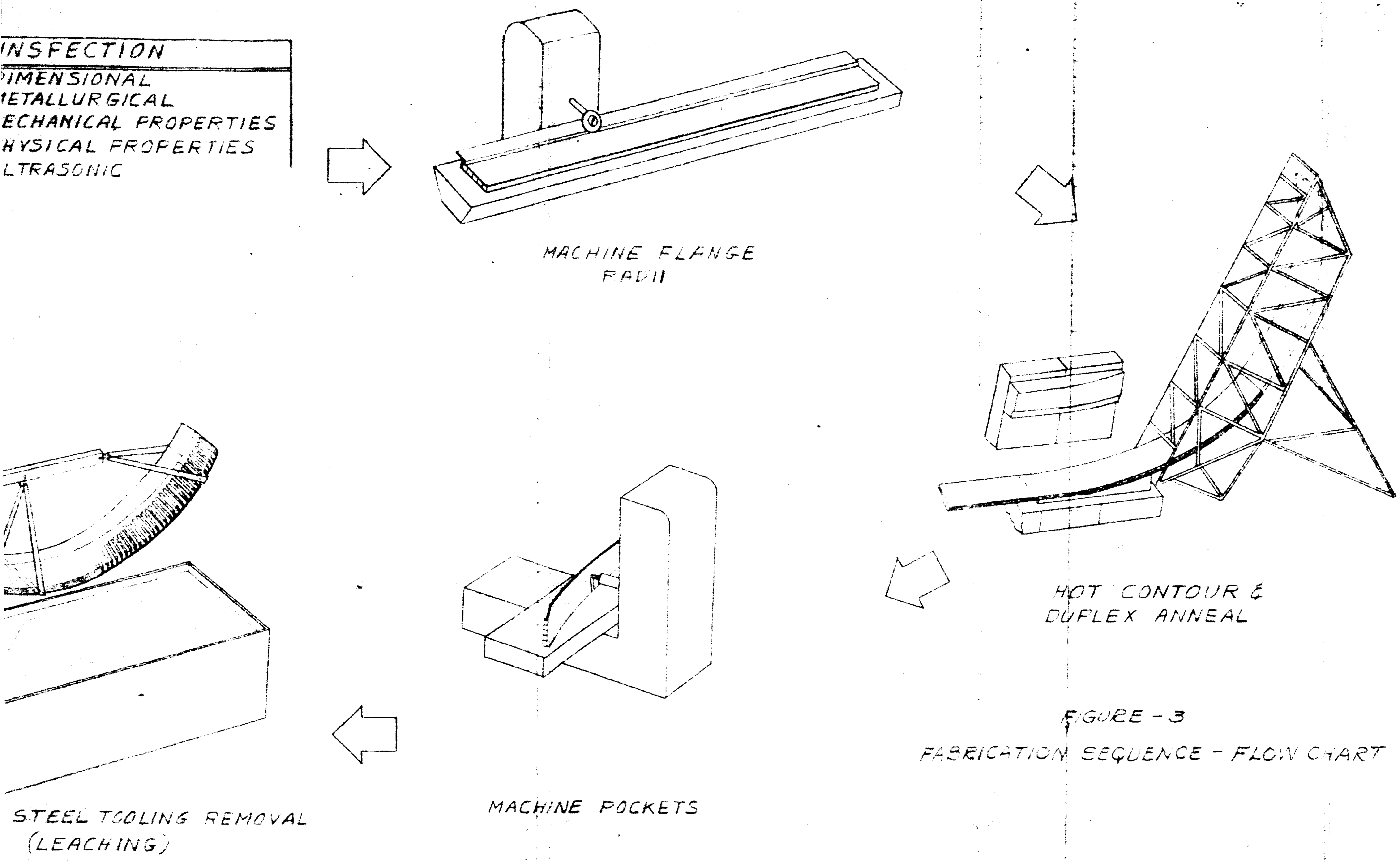
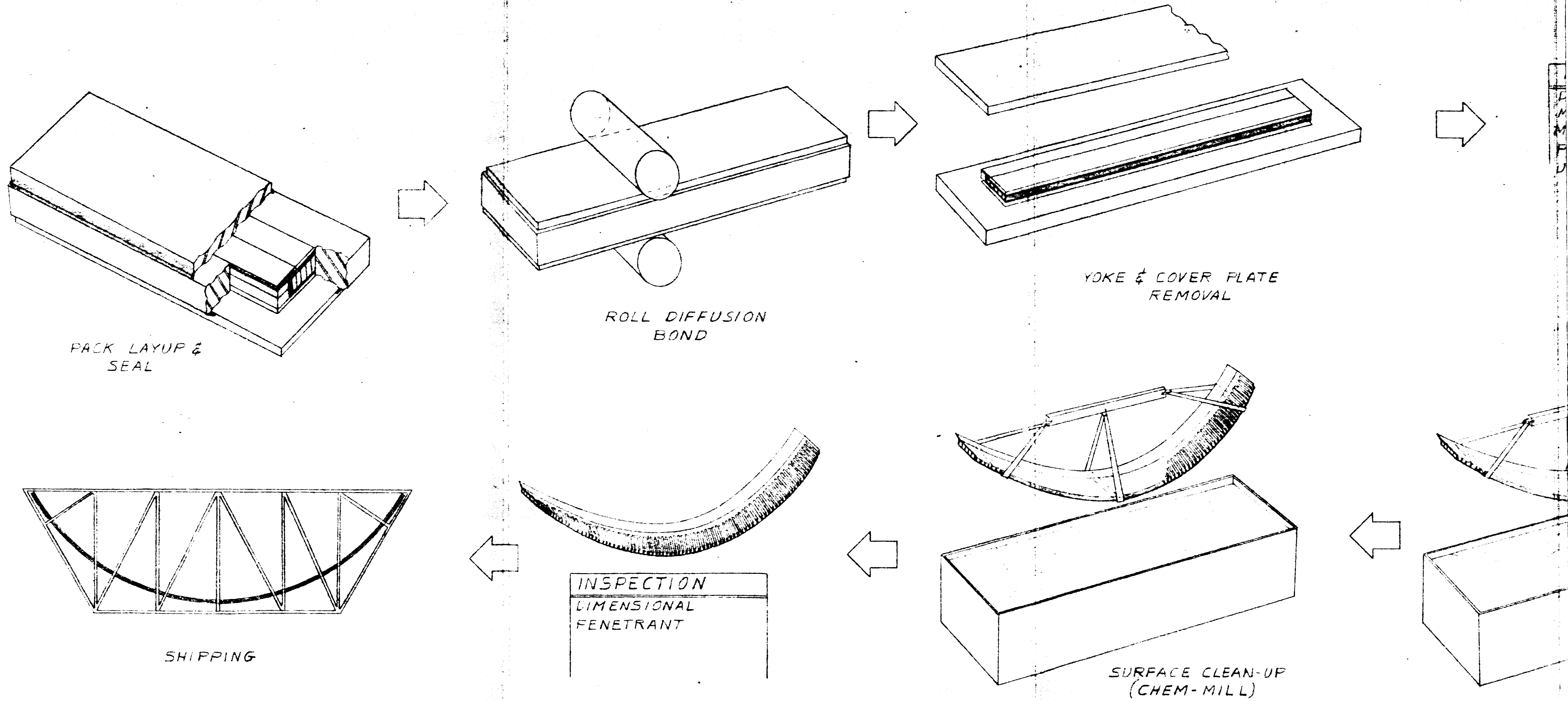


FIGURE - 3

FABRICATION SEQUENCE - FLOW CHART


PACK LAYUP & SEAL
ROLL DIFFUSION BOND
YOKE & COVER PLATE REMOVAL
SURFACE CLEAN-UP (CHEM-MILL)
INSPECTION
DIMENSIONAL
PENETRANT
SHIPPING

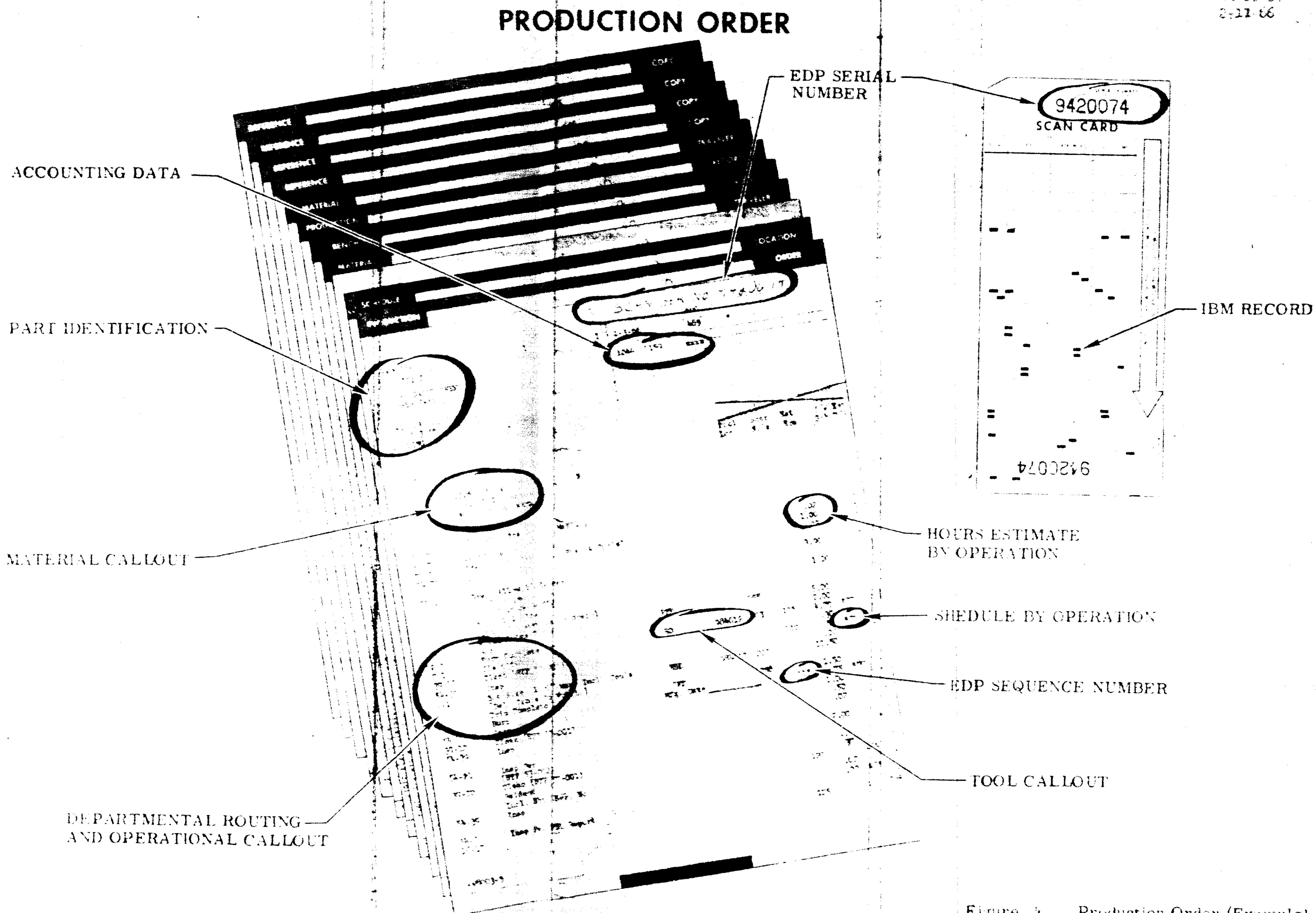


Figure 4. Production Order (Example)

these details will be sent to the Mill Polishing Company for removal of mill scale and grinding to pack lay-up dimensions.

ASTM A-7 steel yoke material for encasing the pack details has been ordered from United States Steel. This material order consists of two plates 9 inches thick x 44 inches wide x 160 inches long. After receival, a plug 9 inches x 20 inches x 144 inches will be flame-cut from the center of each plate leaving a rough yoke detail. These yokes will then be surface ground to a finished pack lay-up thickness and the internal cavity of each will be machined to final pack lay-up dimensions.

The internal support tooling and the cover plates are also ASTM A-7 steel material and these details have been procured from various local suppliers. These details are being inspected by NAA/LAD receiving inspection.

Table I presents the weights of the individual details for one full-scale pack. Also included is the completely assembled pack weight, and the reduction of weight as fabrication progresses.

PACK LAY-UP AND SEAL

Figure (5) shows the pack assembly drawing for the lay-up and sealing of the packs. This drawing and Process Specification 2623-007 entitled "Roll Diffusion Bonding of Y-Ring" will be used for lay-up and roll diffusion bonding.

Location

The lay-up of the two full scale Y-Ring packs will be accomplished in the large clean room, Figure (6), located in Building 92 of NAA/LAD. This room is air-cooled, and the air is filtered and dehumidified so that clean, moisture-free details can be realiably assembled for bonding.

Cleaning

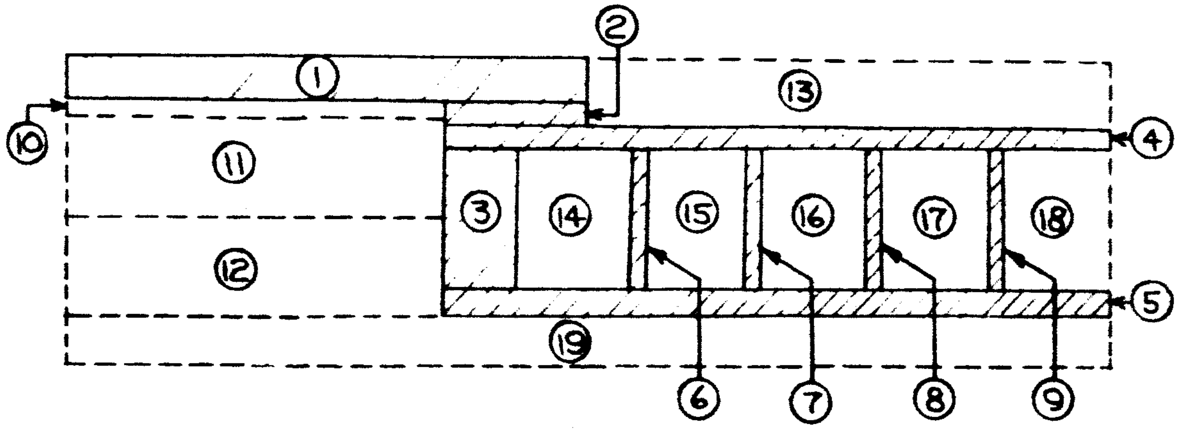
The titanium details for the two packs will be individually cleaned by flash chem-milling per NAA/LAD Process Specification LA0103-003 prior to lay-up assembly. The steel details including the yoke and cover plates will be abrasively cleaned and solvent wiped prior to lay-up assembly.

Handling equipment, including portable hydraulic lifts, lift trucks, and 14,000 pound overhead bridge cranes, is available for handling the individual pack details.

Assembly

The pack assembly sequence is anticipated as follows:

1. MIG weld bottom cover plate to yoke.
2. Position yoke on a reinforced dolly with wheels under the 14,000 pound bridge crane in the clean room, Figure (6).



	Individual Part Weight (lbs)	Total Part Weight In Pack (lbs.)
External Steel Tooling		
Yoke	9675	9,675
Cover Plate	5638	11,275
Internal Steel Tooling		
-10 filler bar	97	97
-11 & -12 filler bar	734	1468
-13 filler bar	577	577
-14 thru -18 filler bar	510	2550
-19 filler bar	1040	1040
Shim Stock		100
Titanium Details		
-1 flange	184	184
-2 doubler	25	25
-3 ring	161	161
-4 & -5 face sheet	175	350
-6 thru -9 rib	26	104
TOTAL PACK WEIGHT		27,606
Pack Wt. After Flame Cutting		12,600
Pack Wt. After Cover Plate Removal		6,000
Wt. After Removal of Internal Tooling (Except -14 thru -18)		3,314
Wt. After Flange Machining & Length Trim		3,145
Wt. After Pocket Machining		1,402
Y-Ring Wt. After Leaching		512
Y-Ring Wt. After Chem-Milling		480

TABLE I
TABLE OF WEIGHTS

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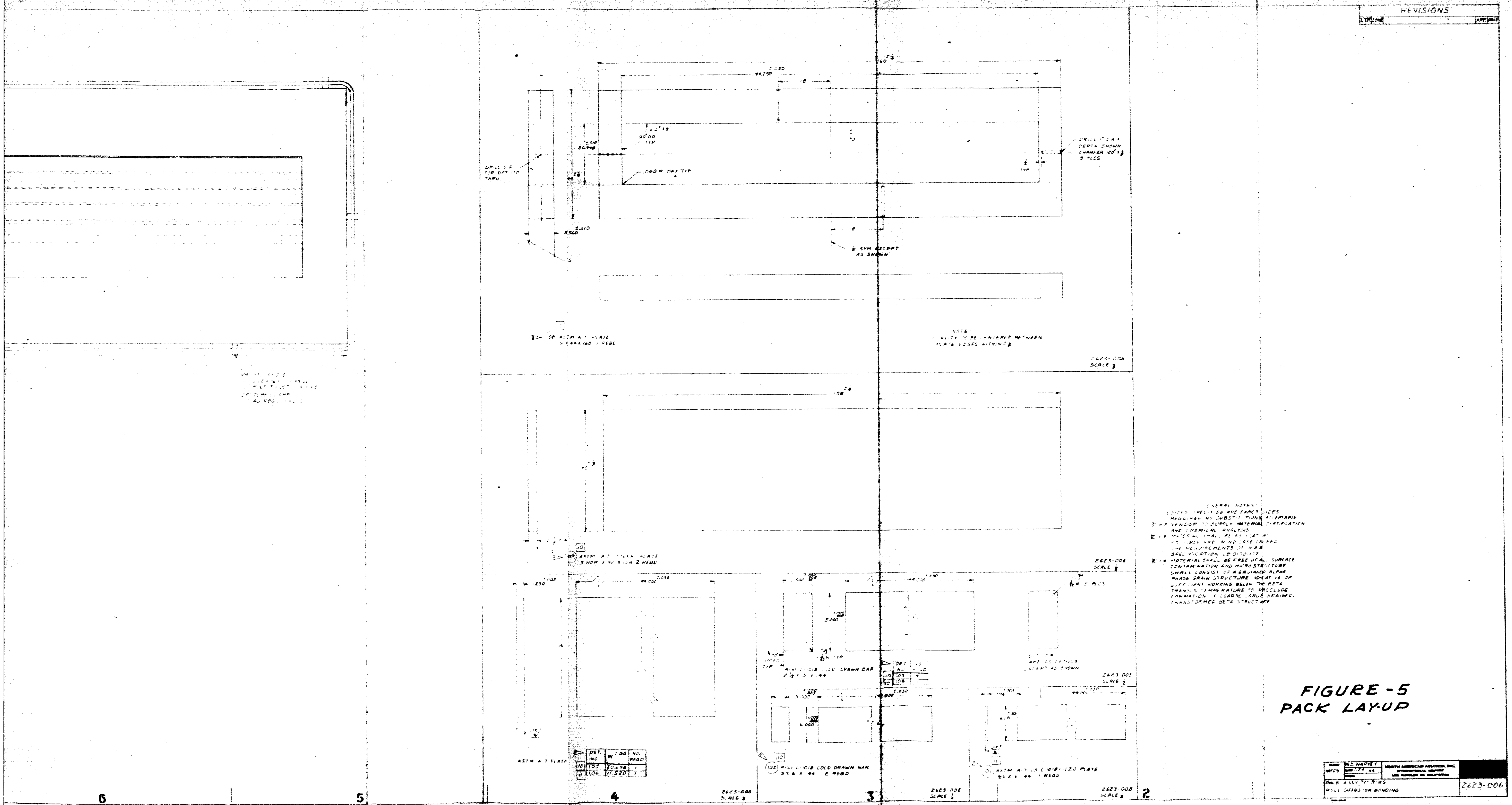


FIGURE - 5
PACK LAY-UP

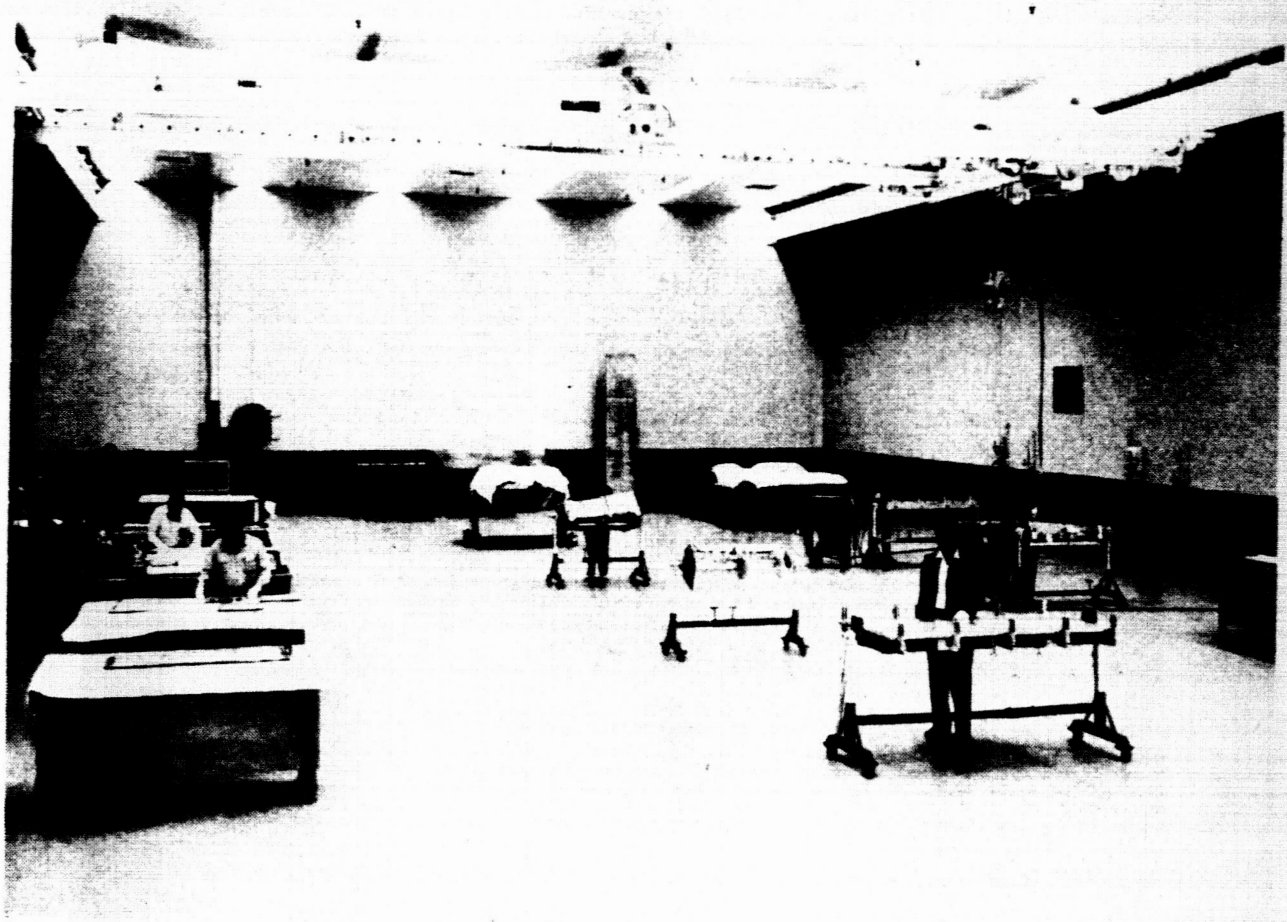


FIGURE 6. CLEAN AREA AND LAY-UP ROOM

3. Place detail parts inside the yoke as shown in the pack assembly drawing, Figure (5). This assembly will be accomplished in much the same manner as that of the developmental packs with the exception of size. Figure (7) shows the details for assembly of one of the developmental packs. Figure (8) shows the titanium and steel stack-up without the surrounding yoke, and Figure (9) show the pack partially assembled.
4. MIG weld the top cover plate to the yoke.

Handling of the assembled packs will be accomplished with 15 ton lift trucks.

ROLL DIFFUSION BOND

Rolling Mill

The roll diffusion bonding will be accomplished at either the Bethlehem Steel Mill in Sparrows Point, Maryland, or the United States Steel Mill in Gary, Indiana. Both candidate steel mills have the facilities and the capability to roll the full-scale packs and price negotiations are to be completed prior to the final mill selection. Figure (10) shows the Bethlehem Steel 160" 4-high reversing mill and Figure (11) shows the United States Steel 160/210 inch plate mill.

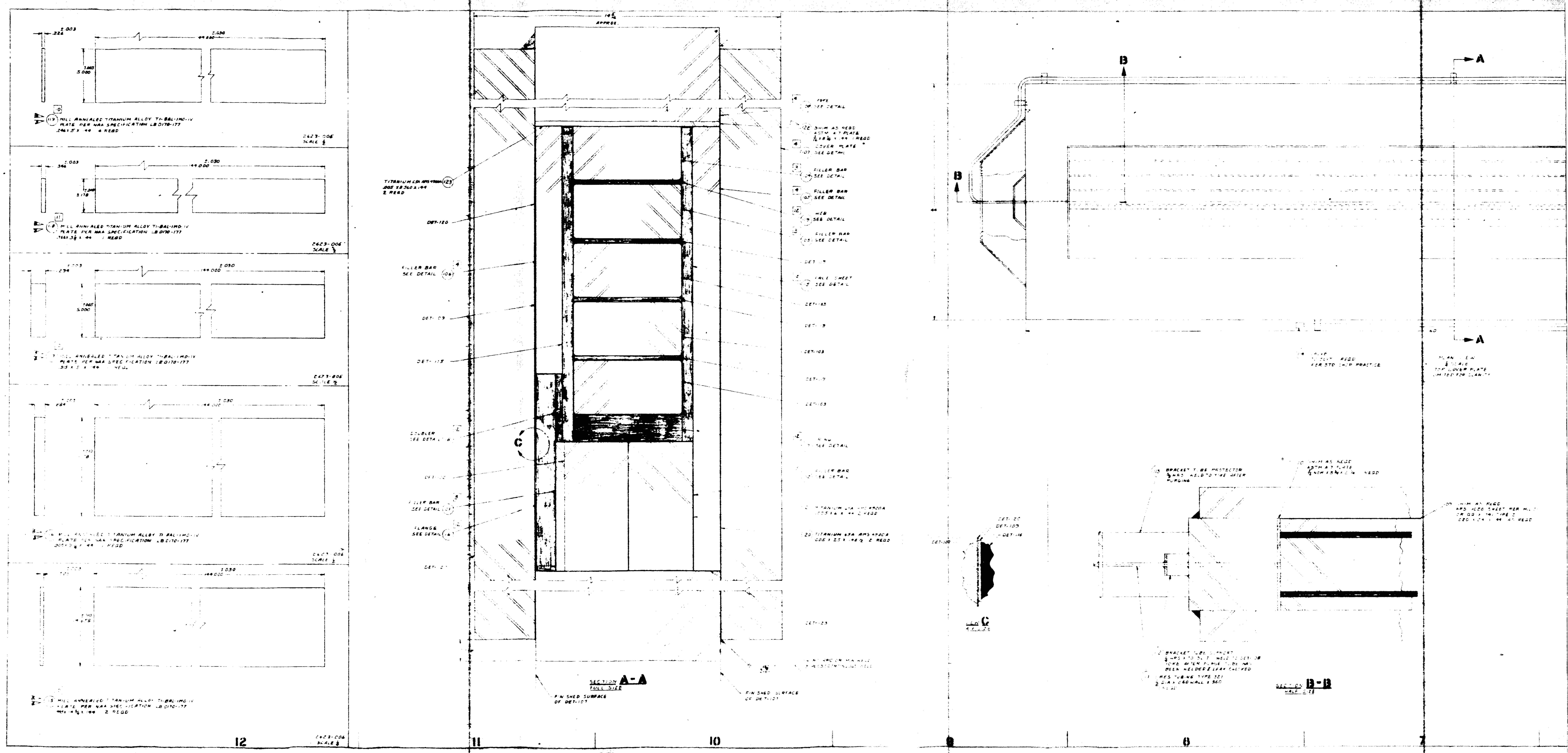
Shipment to Rolling Mill

Each pack, as assembled, will measure 14-1/2" x 44" x 160" and will weigh approximately 28,000 pounds. Various means of transportation have been considered for shipment of the two full-scale packs to the selected rolling mill. These include railroad car, motor truck, and air freight. Railroad car requires from 10 to 14 days one way back to the rolling mill at a cost of approximately $650 per pack. The fabrication schedule prohibits this long travel time. Air freight was considered, and the travel time was excellent, however a chartered plane at a cost of $11,000 per pack prohibits this method of transportation. Motor truck requires 5 to 6 days travel time for approximately $650 per pack. This means of transportation is considered optimum and is anticipated for use.

Rolling

Each pack will be heated to a rolling temperature of 1835°F. A total heat-up and soak time of 15 hours minimum is anticipated and each pack will be continuously evacuated during heat up to a minimum temperature of 1600°F.

Upon completion of the heat-up and soak time, each pack will be rolled to the finished gage in approximately 5 minutes. A 66.5 percent reduction is anticipated which will increase the pack length approximately three times. Figure (12) shows a developmental pack prior to rolling and Figure (13) shows the same pack after rolling.



MILL ANNEALED TITANIUM ALLOY TI-8AL-1MO-1V
PLATE PER NAA SPECIFICATION LB0170-177
2623-006
SECTION A-A
FULL SIZE
DET-120
FILLER BAR
SEE DETAIL
DOUBLER
FLANGE
COVER PLATE
WEB
TITANIUM
SECTION B-B
HALF SIZE
FINISHED SURFACE OF DET-107
12
11
10
9
8
7

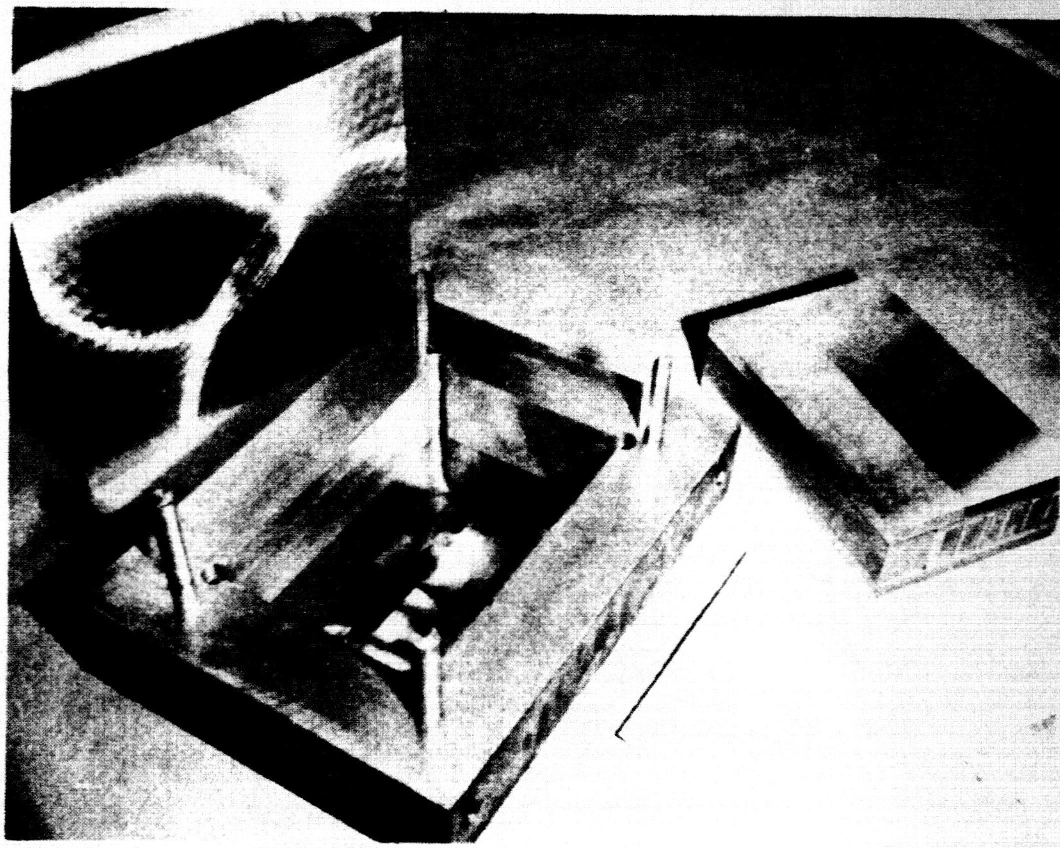


FIGURE 7. DEVELOPMENTAL PACK LAY-UP DETAILS

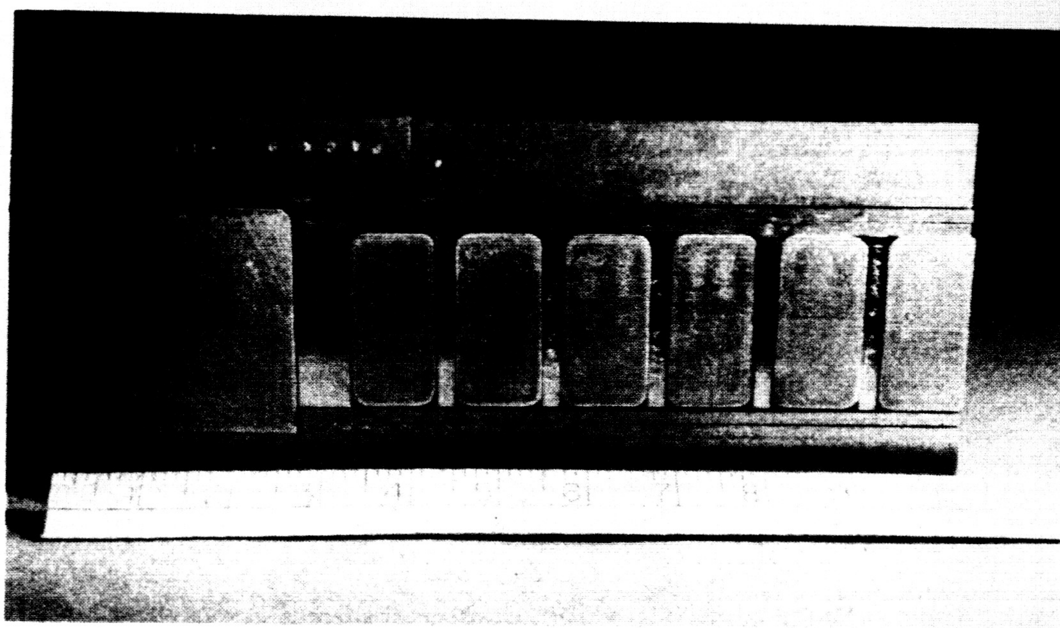


FIGURE 8. DEVELOPMENTAL PACK DETAIL STACK-UP

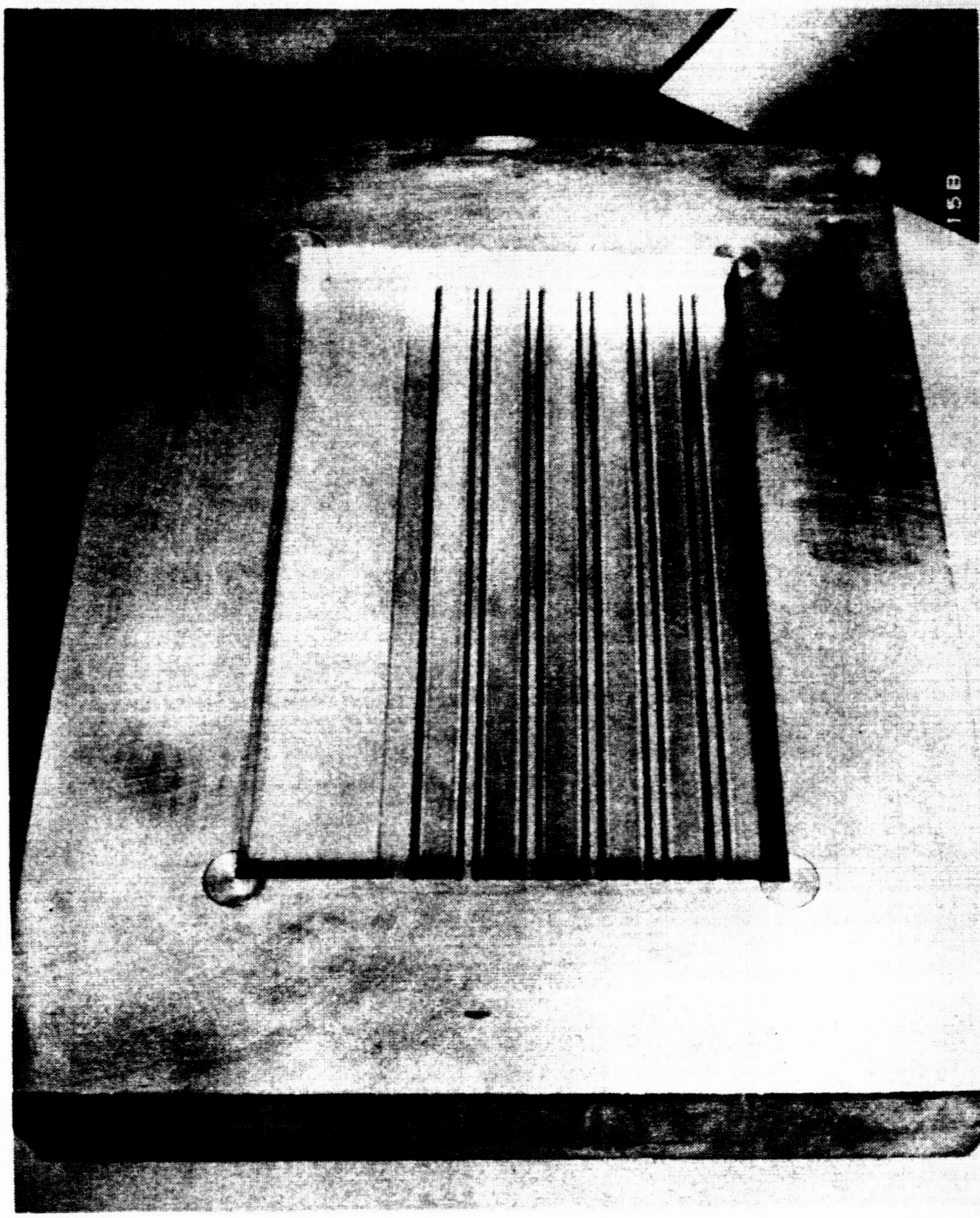


FIGURE 9. DEVELOPMENTAL PACK LAY-UP

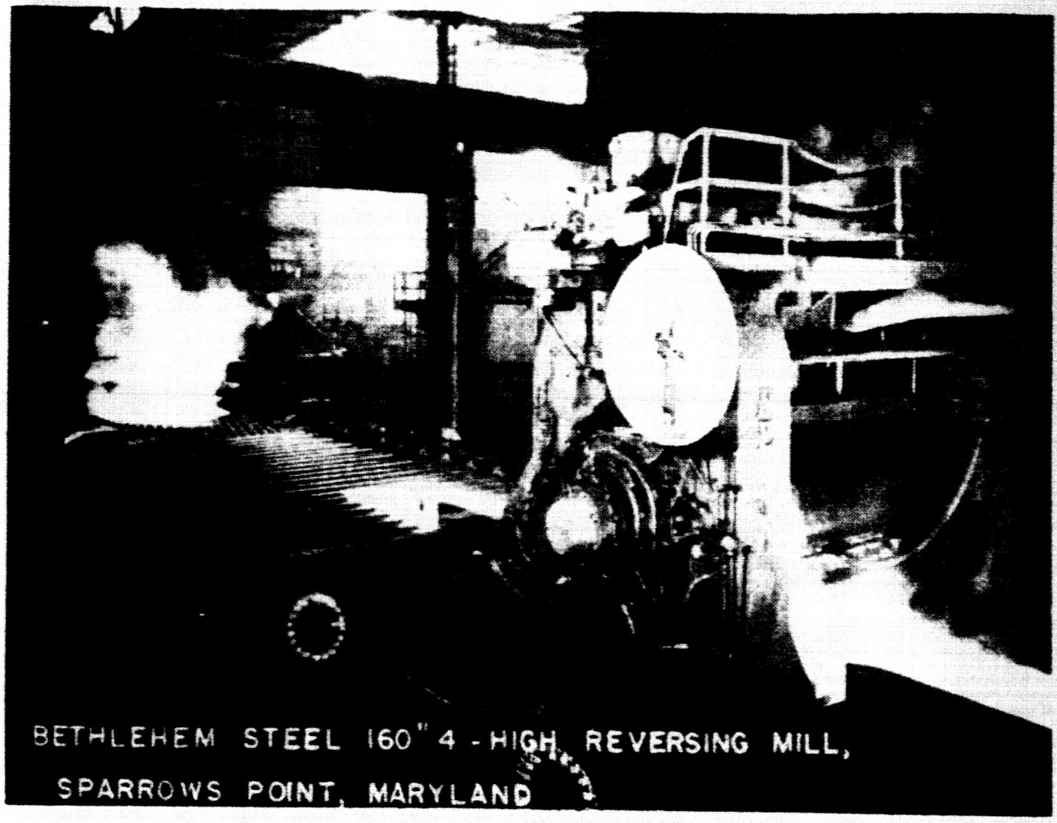


FIGURE 10

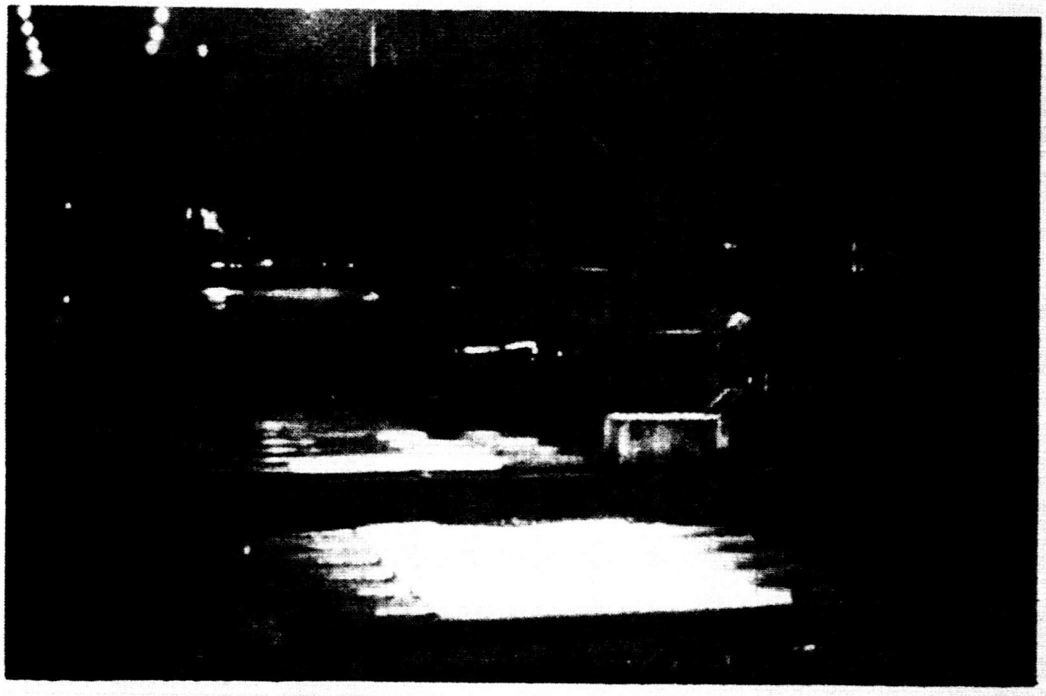


FIGURE 11. UNITED STATES STEEL 160/210" ROLLING MILL

FIGURE 12. DEVELOPMENTAL PACK PRIOR TO ROLLING

FIGURE 13. DEVELOPMENTAL PACK AFTER ROLLING

YOKE AND COVER PLATE REMOVAL

Flame Cutting

After rolling, the steel yoke will be flame cut away from the rolled titanium structure and the outer cover plates will be mechanically removed. This will reduce the weight of the packs approximately 88 percent. Figure (14) shows the flame cutting operation being performed on one of the developmental packs.

Shipment to NAA/LAD

Each pack will measure 2-1/2" x 21" x 421" and will weigh approximately 3300 lbs. for shipment back to NAA/LAD. Air freight is anticipated as the transportation method at a cost of approximately $600 per pack. This will expedite the succeeding fabrication operations.

INSPECTION

Dimensional

Both ends of each pack will be trimmed and a cross-sectional specimen similar to that shown in Figure (15) will be polished and the internal steel tooling removed for accurate dimensional measurements which will be compared to the design drawing No. 2623-005. These measurements will be recorded and submitted in the final report.

Metallurgical

Metallurgical specimens will be cut from various rib-to-skin and flange locations in the pack trim areas and examined metallographically. Bond quality will be inspected and any evidence of contamination, metallurgical phase transformation, or notched joints will be recorded and submitted in the final report.

Physical Properties

Chemical analyses will be conducted using specimens taken from the trim ends of each pack to determine the interstitual pick-up or nitrogen, hydrogen, carbon, and oxygen by the titanium material during the roll diffusion bonding process. Data from these examinations will be submitted in the final report.

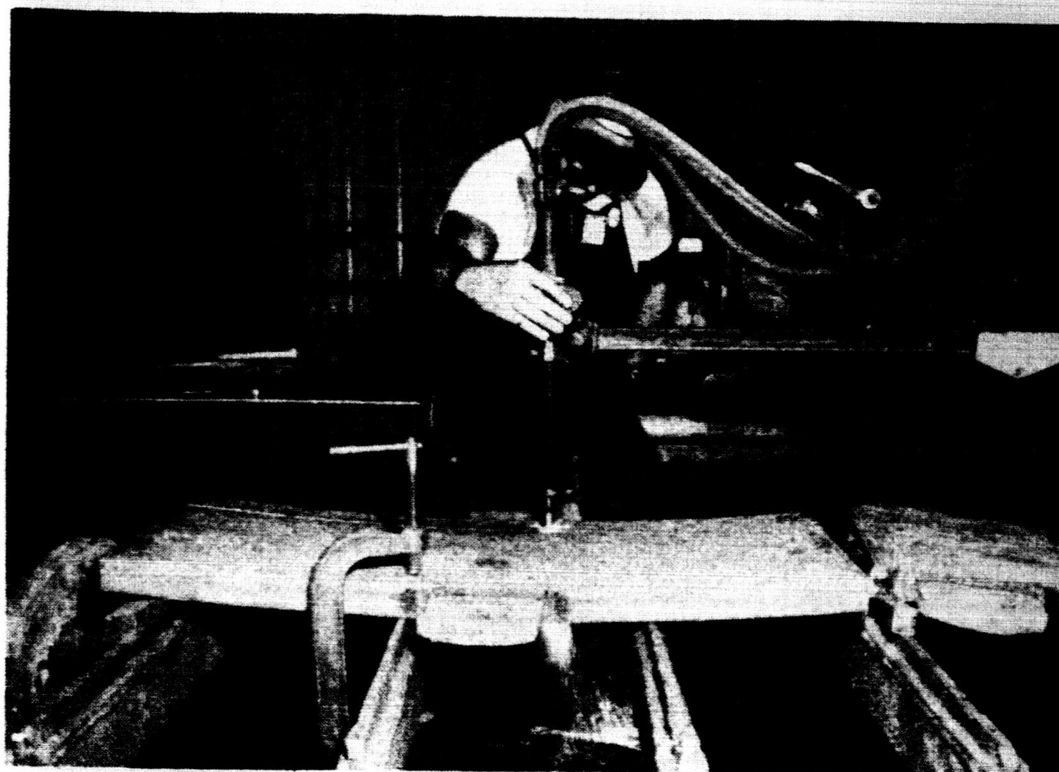


FIGURE 14. FLAME CUTTING DEVELOPMENT PACK

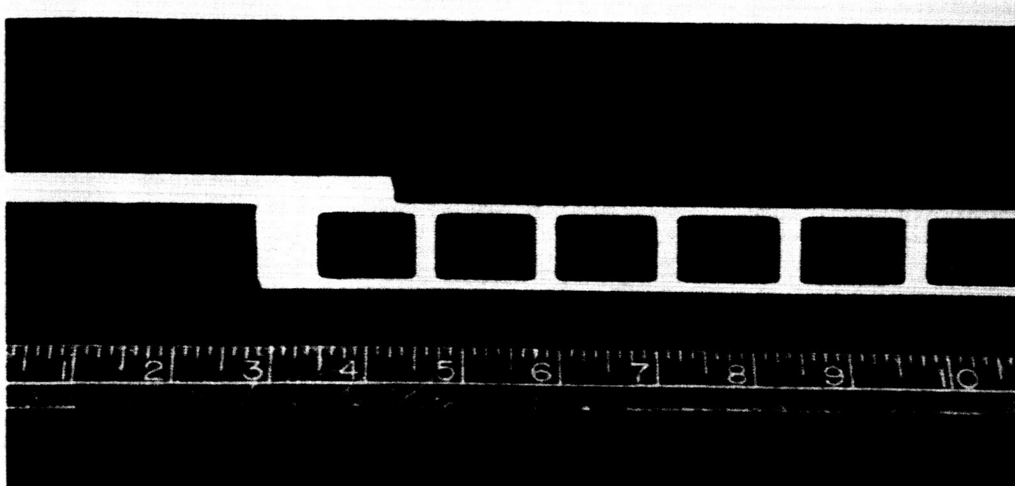


FIGURE 15. DEVELOPMENTAL PACK CROSS-SECTION

MACHINING FLANGE RADII

Location

NAA/LAD has the facilities, equipment, capabilities and experience to perform the required machining operations on the Y-Ring segments after rolling; however due to the projected work load for this equipment, it is anticipated that an outside machine shop perform the required machining operations.

Handling

For flange machining, the part will be flat and the exposed surfaces of titanium will be protected during handling. Wooden skids are anticipated for use and conventional lifting equipment will be employed to assist transportation by NAA truck to and from a selected machine shop.

Machining

Three machine operations will be performed on the full-scale Y-Ring segments prior to forming while the part is in the flat condition. The full-scale cross section of a Y-Ring segment and the trim areas are shown in Figure (16) A 12 inch radius cut similar to that shown in Figure (17) will make the flange runout tangent to the inner skin of the rib-stiffened area. A 0.38 inch radius similar to that shown in Figure (18) will eliminate the sharp corner resulting from rolling. The tangent points of both radii on the flange are to be 1/8 inch apart. This will assure proper fit-up with the hot contour forming die and will maintain the proper crossectional dimension in the machined area.

The edge trim will be left 1/4 inch oversize to assure proper assembly fit-up.

HOT CONTOUR AND DUPLEX ANNEAL

Concept

Each Y-Ring segment will be contoured to a 198 inch radius. Several methods were evaluated for accomplishing this task with an incremental hot form/size technique being selected as the most practical and most economical for this particular development effort. Figure (19) and (20) show the incremental forming concept. It is also anticipated that upon exit from the hot contouring die, the formed part will air cool fast enough to obtain the duplex anneal properties desirable for subsequent weld joining.

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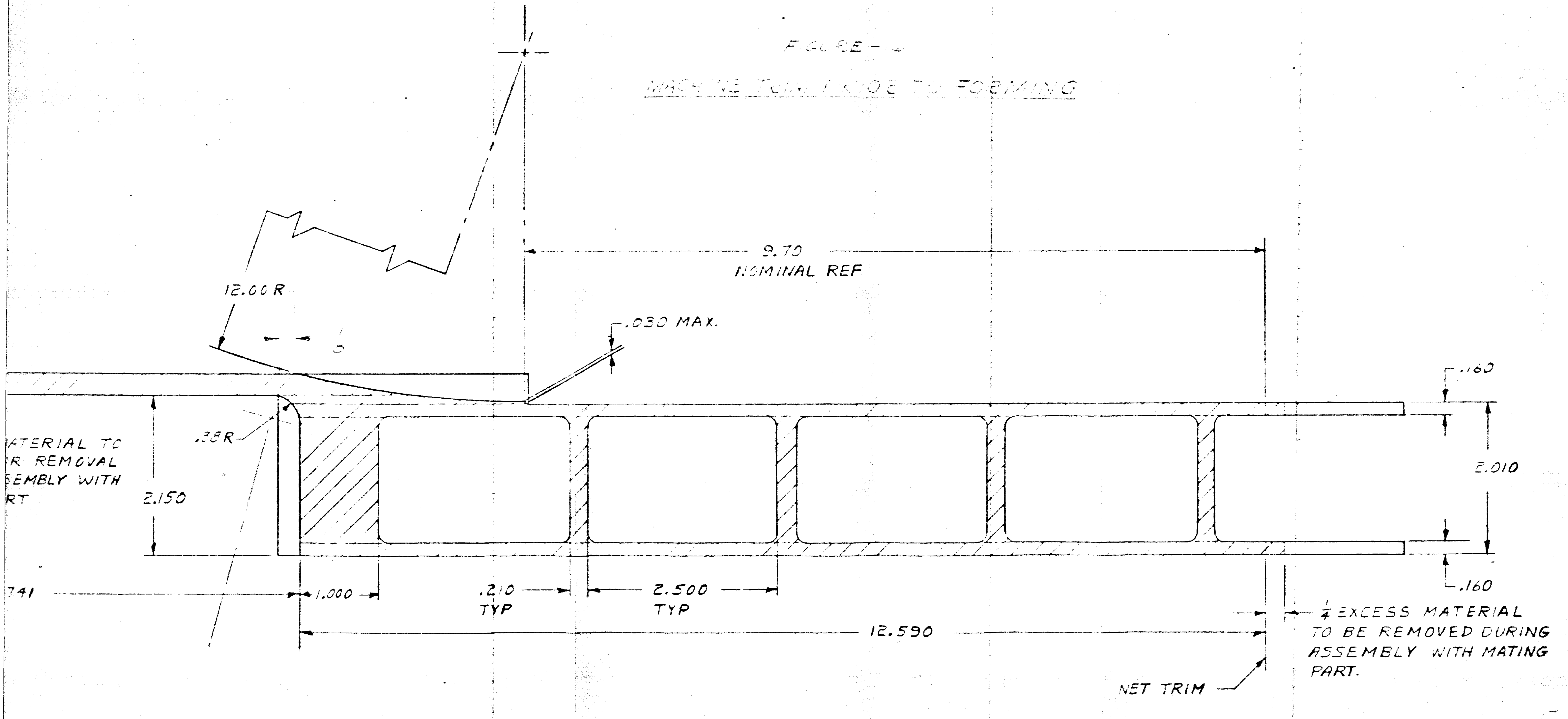
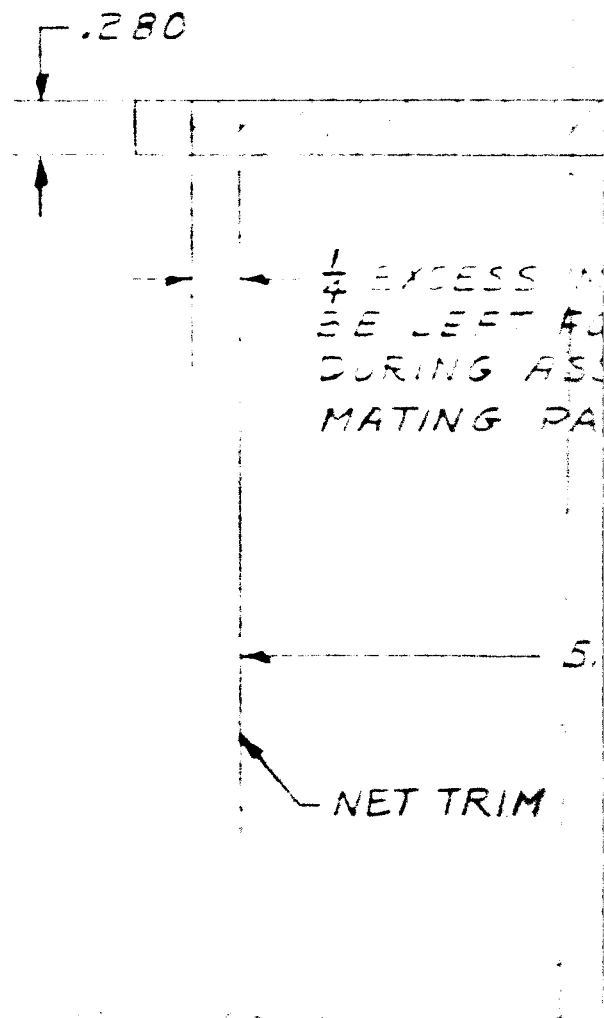
FIGURE – 14

MACHINE TUN PRIOR TO FORMING




.280
NET TRIM

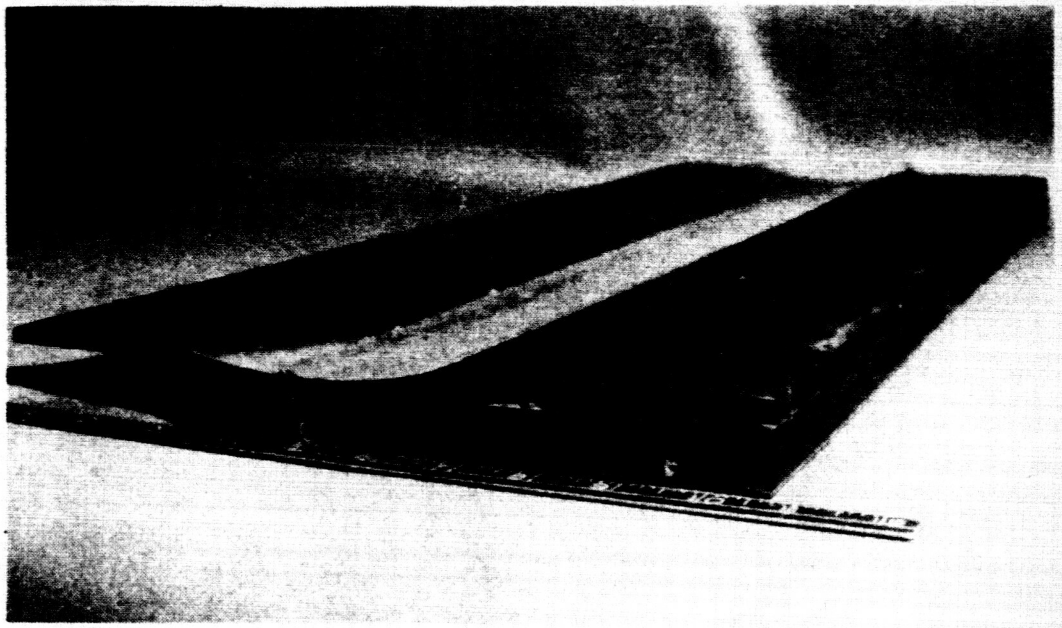


FIGURE 17. MACHINED DEVELOPMENTAL PACK FLANGE RADII

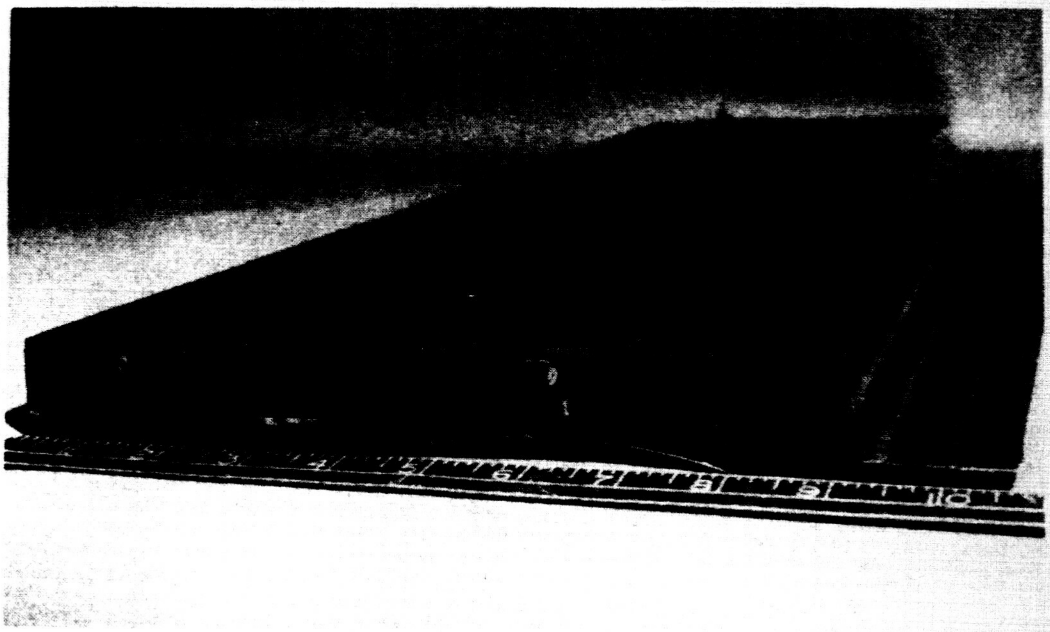


FIGURE 18. MACHINED DEVELOPMENTAL PACK FLANGE RADII

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Y-RING, HOT CONTOUR FORMING CONCEPT

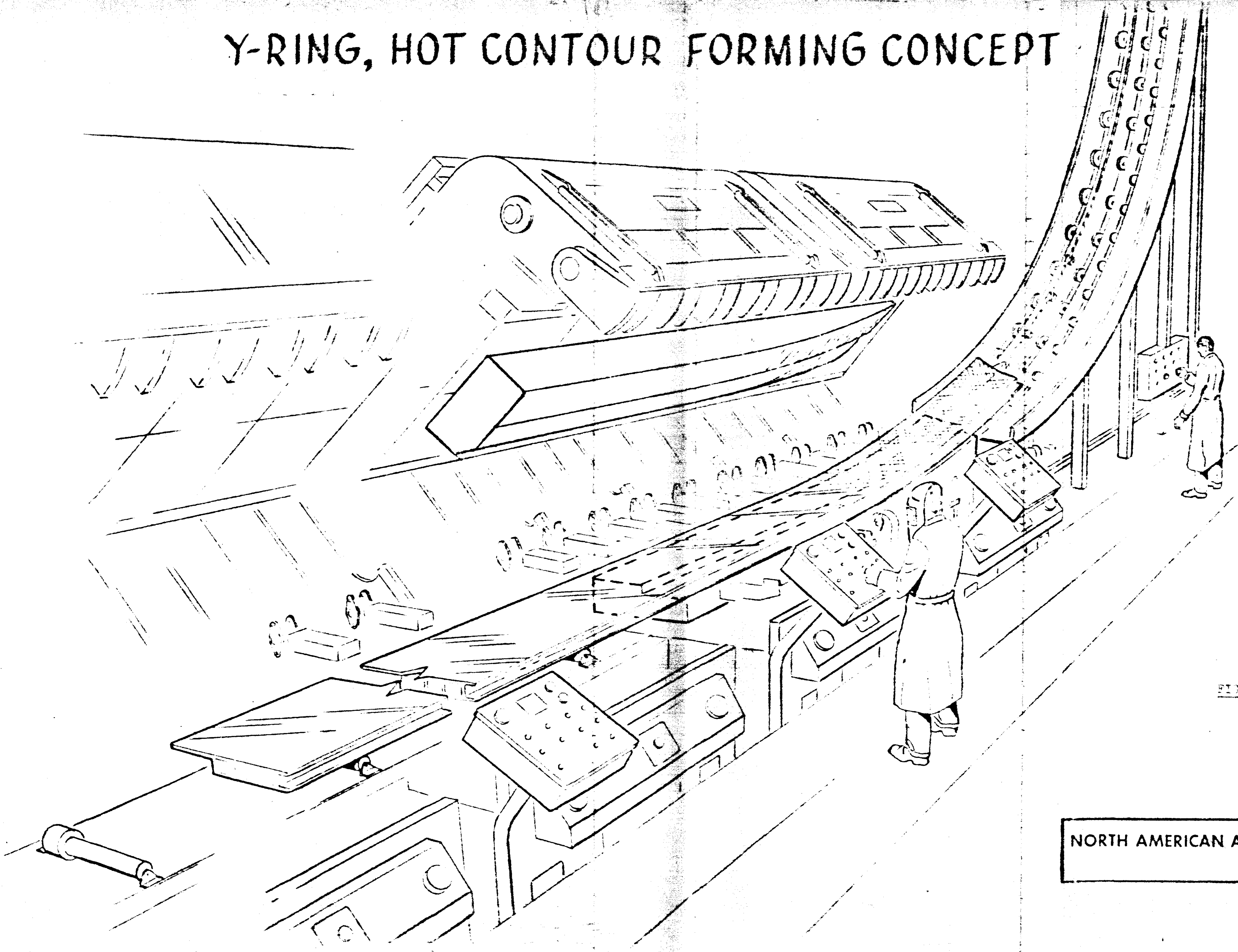

FIGURE 19

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Y-RING, HOT CONTOUR FORMING CONCEPT

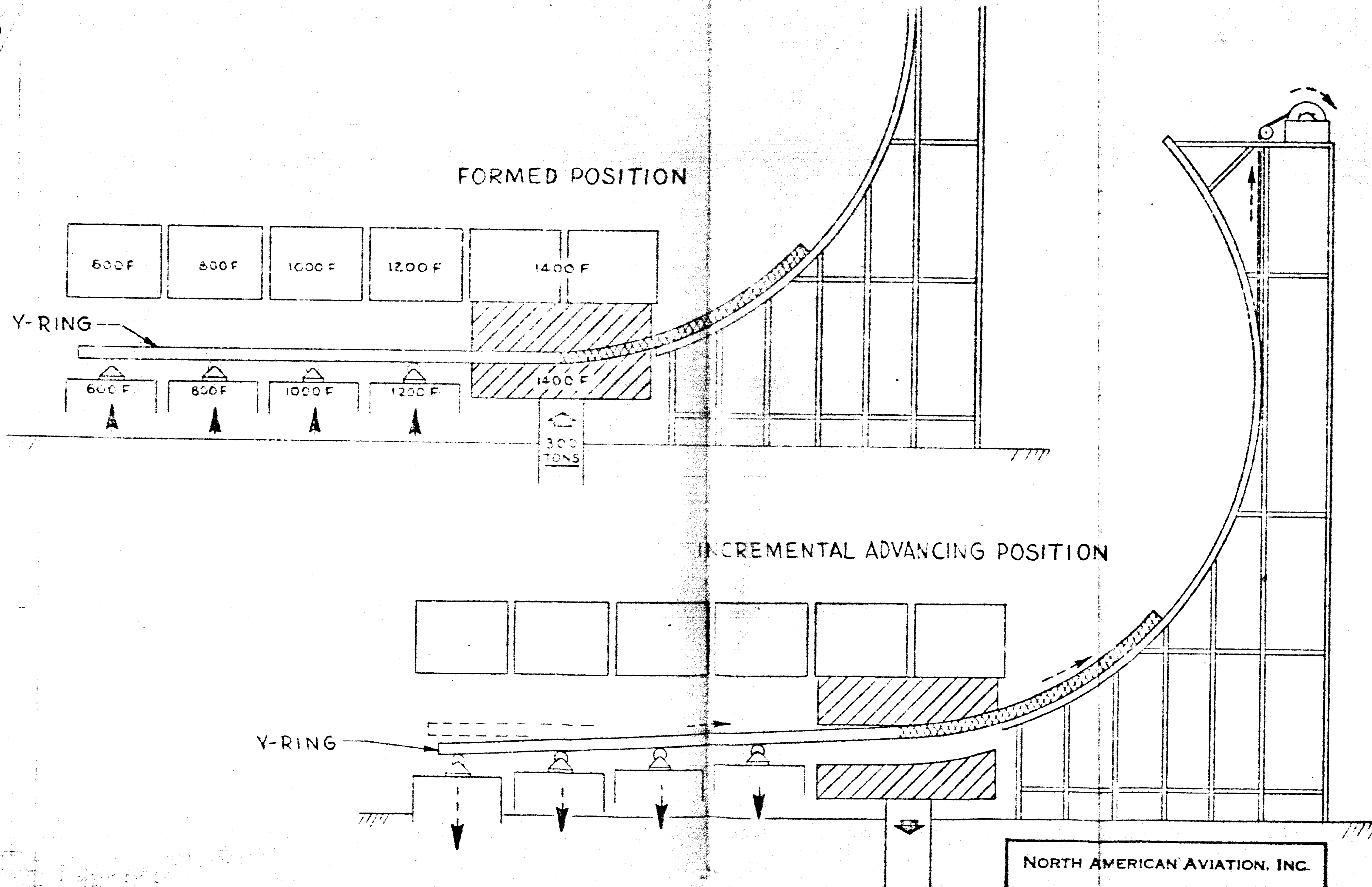

FIGURE 20

NORTH AMERICAN AVIATION, INC.

Process Support Mechanisms

1) Hot Contour Forming Die 2623-201

The hot contour forming die, Figure (21), is a mated, cast and machined meehanite tool 6 feet long, capable of maintaining high strength at 1450F, and mounted in the existing Sheridan-Gray hot-size press at NAA/LAD Figure (22). Essentially, this tool consists of 3 zones described with their operation as follows, 1) 18-inches of lead in which conforms to the cross-sectional shape of the flat and straight part. This zone accomplishes alignment and pre-heating functions for forming in the subsequent two stages. 2) 18-inches of ramped transition of the .280 inch thick flange from flat to the 13° formed up position. 3) 36-inches of 198 inch contour for the part body and flange completes the die configuration. It is planned to incrementally feed the part from zone 1 into, and through, zones 2 and 3 in approximately 6 inch incremental advances with a forming load of 300 ton applied for about 10 minutes following each advance. The entire tool is heated to 1450F by conduction from the hot size press which has upper and lower heating plattens capable of achieving 1850F. The double contouring of a smaller (40 inch) part has been demonstrated as shown in Figure (23).

2) Handling Fixture 2623-202-1,-2

This fixture, detailed in Figures (24) and (25), is designed as a multipurpose unit specifically for this project. It will perform initially as a receiving fixture for receiving the Y-Ring segment as it progressively moves out of the hot contour forming die. The fixture will be attached to the concrete floor with lag bolts to hold it in position. Since the formed Y-Ring segment will come out of the forming die into a vertical position, a mobile crane, Figure (26), with a 40 foot boom and a cable will be required to lift it into the vertically-mounted fixture. The cable will run through guide rollers in the fixture and be attached to the leading end of the Y-Ring segment with a bolt-on fitting.

On completion of the forming operation the contoured Y-Ring will be nested in the handling fixture and held in place with clamps. The legs supporting the fixture will then be removed and four large casters mounted on the cross bars. The fixture will be lowered down on the casters into a horizontal position. It will then perform as a shipping fixture to safely move the contoured Y-Ring segment to the various locations required for the subsequent machining, leaching and chem-milling operations. Finally the fixture will be used as a cradle for shipping the completed part to MSFC.

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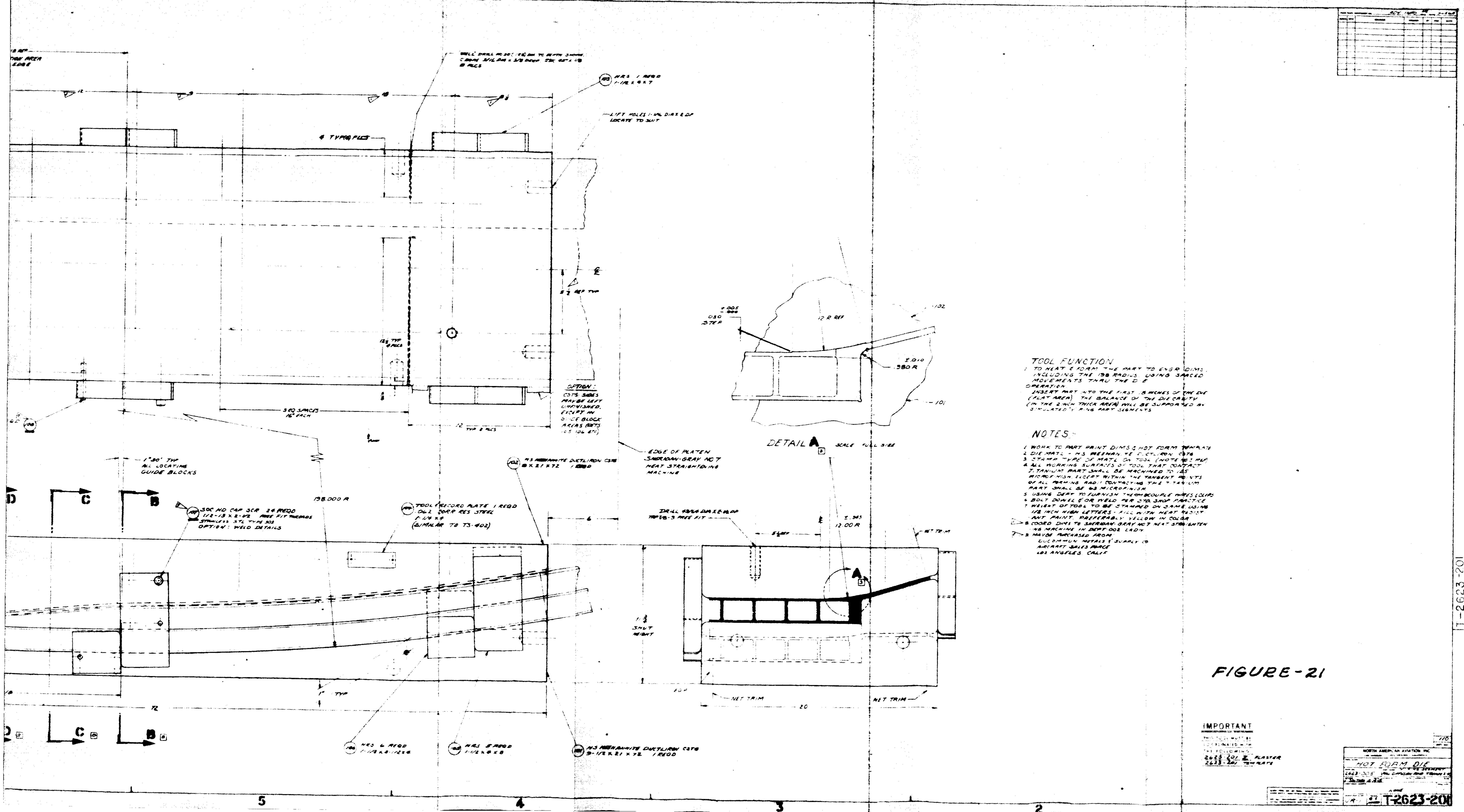
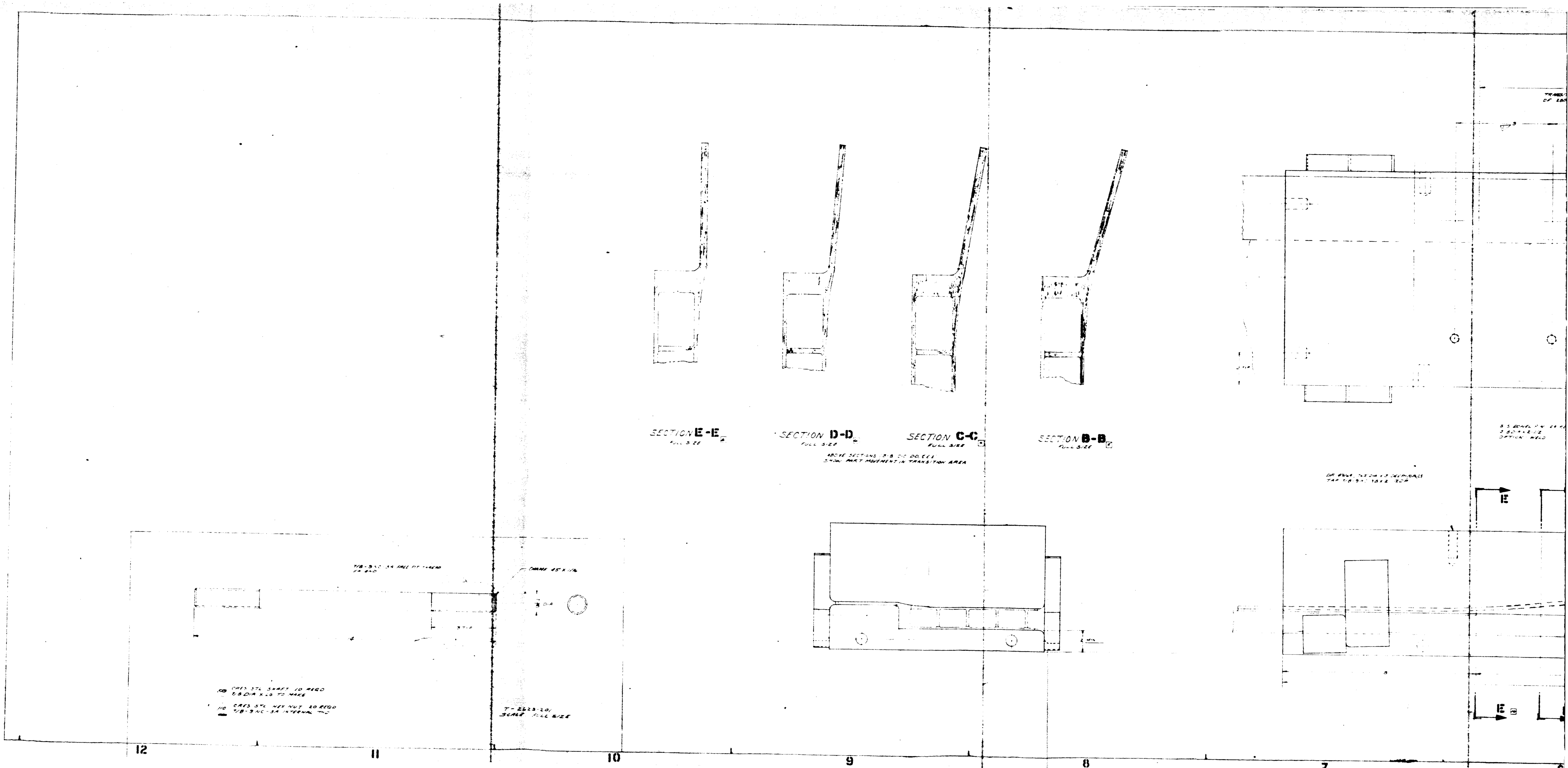


FIGURE-21



SECTION E-E
FULL SIZE
SECTION D-D
FULL SIZE
SECTION C-C
FULL SIZE
SECTION B-B
FULL SIZE
SHOW PART MOVEMENT IN TRANSITION AREA
CRES STL SHAFT 10 REQD
CRES STL HEX NUT 20 REQD
SCALE FULL SIZE
E
E
12
11
10
9
8
7
6

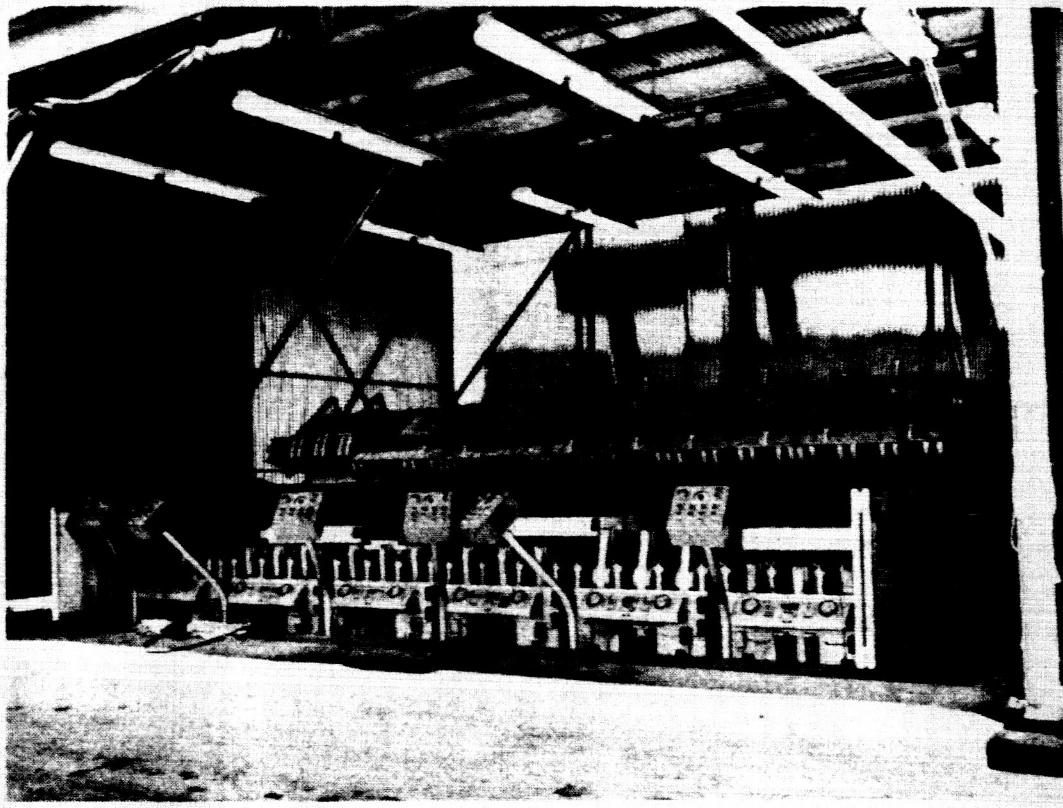


FIGURE 22. HOT SIZING PRESSES AT NAA/LAD

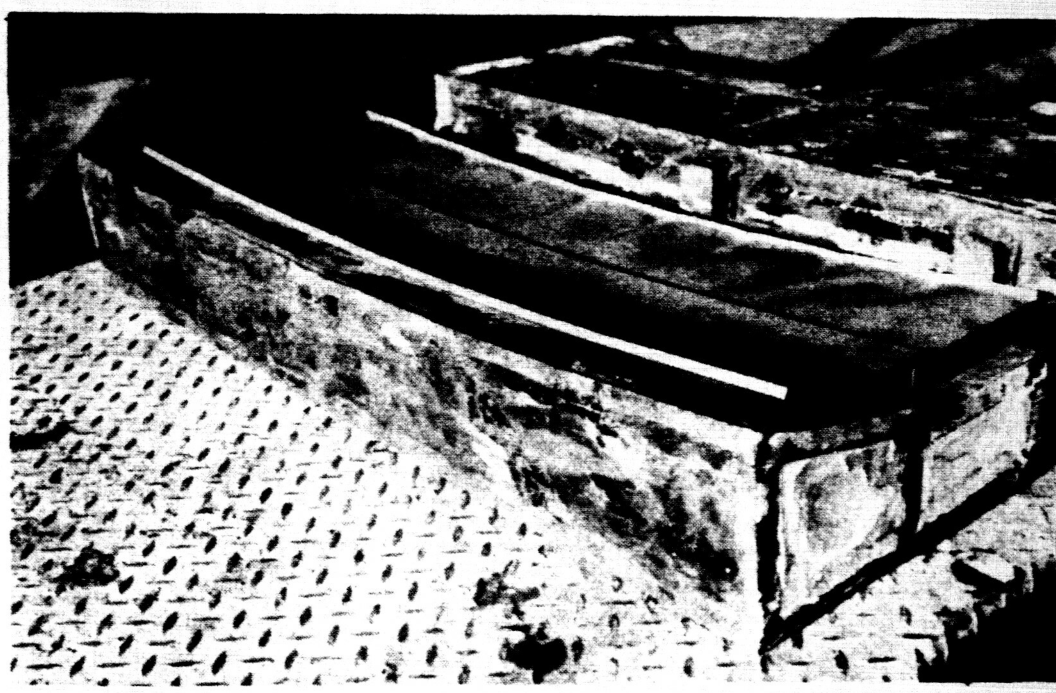
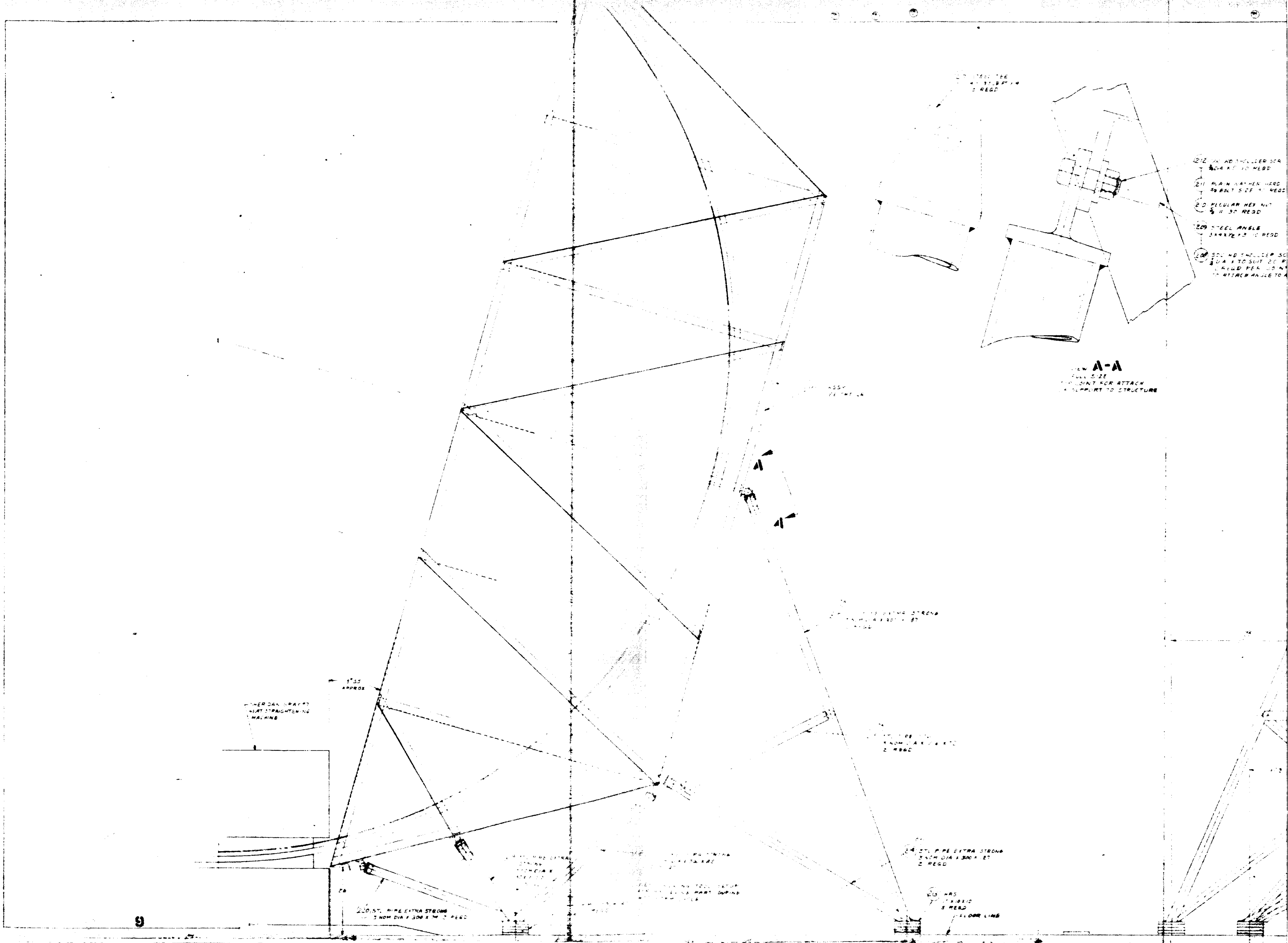


FIGURE 23. DOUBLE CONTOURED DEVELOPMENTAL PACK



A-A
FULL SIZE
SUPPORT TO STRUCTURE
STEEL ANGLE
FLOOR LINE
APPROX

9

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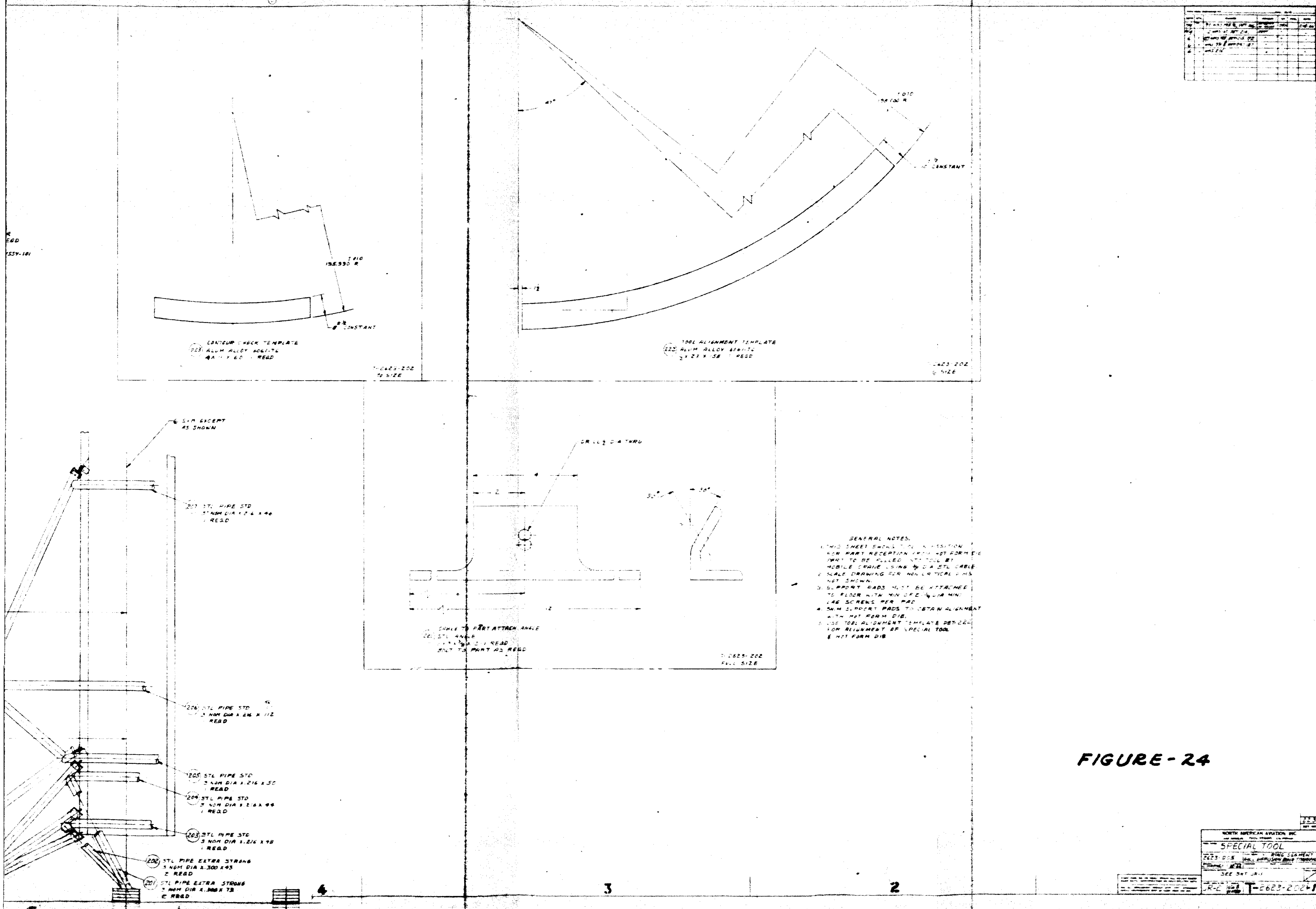
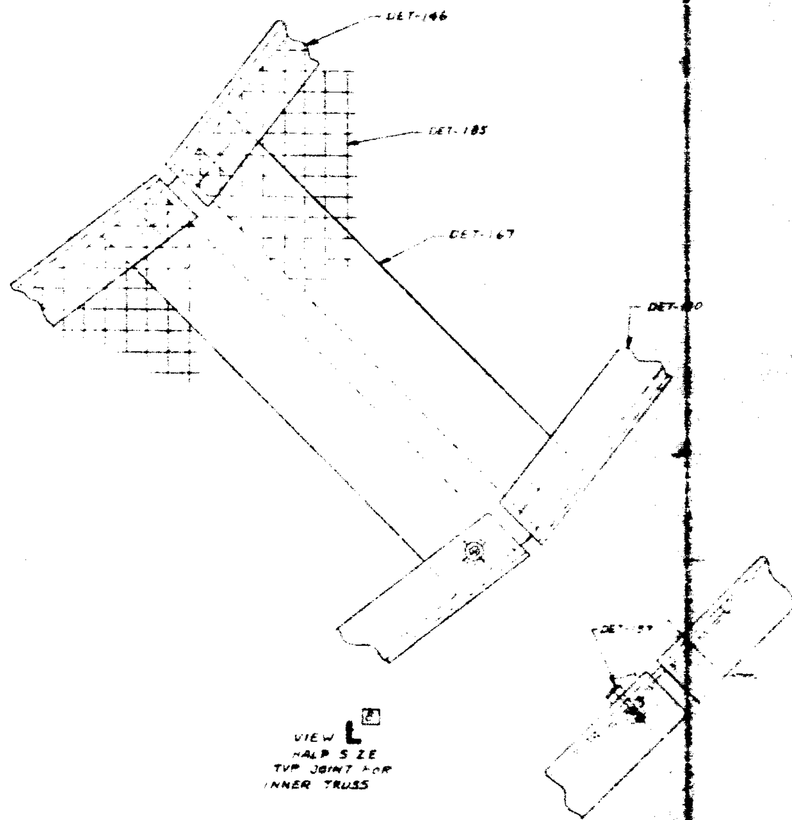


FIGURE-24



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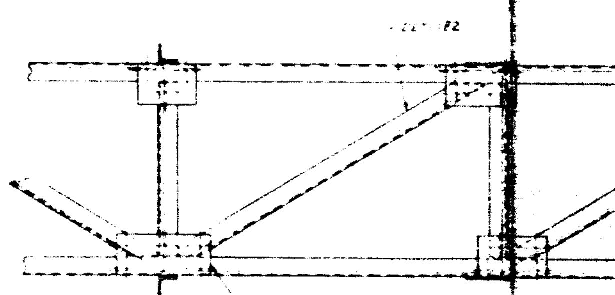
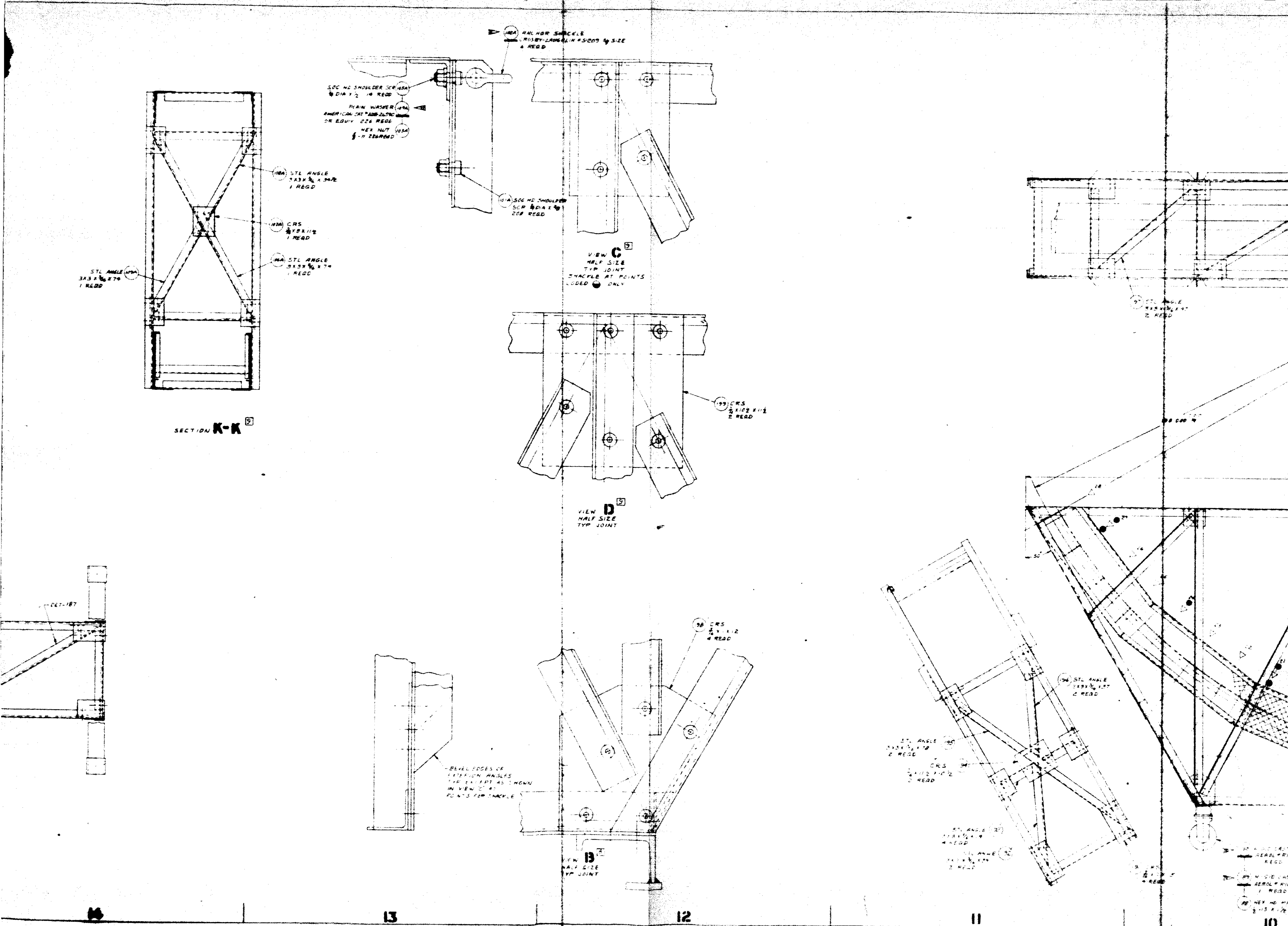
HALF SIZE
TYP JOINT FOR
INNER TRUSS

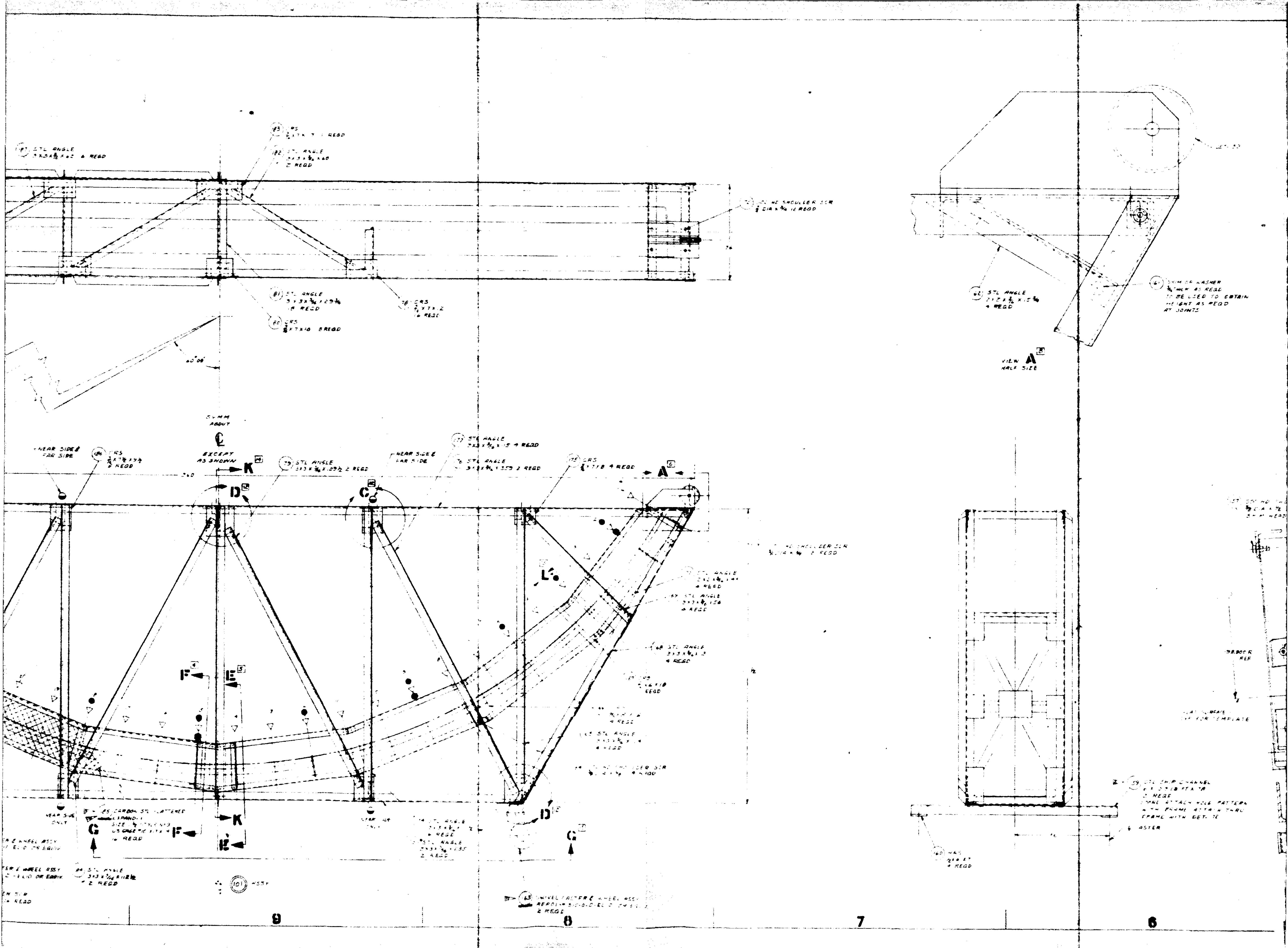


VIEW G-G

16 15



(103A) ANCHOR SHACKLE
CROSBY-LAUGHLIN #S-209 3/4 SIZE
4 REQD
SOC HD SHOULDER SCR (105A)
PLAIN WASHER (104A)
HEX NUT (103A)
(101A) SOC HD SHOULDER
SCR
208 REQD
(108A) STL ANGLE
1 REQD
(107A) CRS
1 REQD
(106A) STL ANGLE
1 REQD
STL ANGLE (105A)
1 REQD
SECTION K-K
VIEW C
HALF SIZE
TYP JOINT
SHACKLE AT POINTS
CODED ● ONLY
(99) CRS
2 REQD
VIEW D
HALF SIZE
TYP JOINT
(98) CRS
4 REQD
BEVEL EDGES OF
EXTERIOR ANGLES
TYP EXCEPT AS SHOWN
IN VIEW C AT
POINTS FOR SHACKLE
VIEW B
HALF SIZE
TYP JOINT
(96) STL ANGLE
2 REQD
STL ANGLE (95)
2 REQD
CRS (94)
2 REQD
STL ANGLE (93)
4 REQD
STL ANGLE (92)
2 REQD
(97) STL ANGLE
2 REQD
14
13
12
11
10


STL ANGLE
CRS
SYMM ABOUT ℄ EXCEPT AS SHOWN
NEAR SIDE & FAR SIDE
VIEW A HALF SIZE
9
8
7
6

NA-66-87
2-11-66

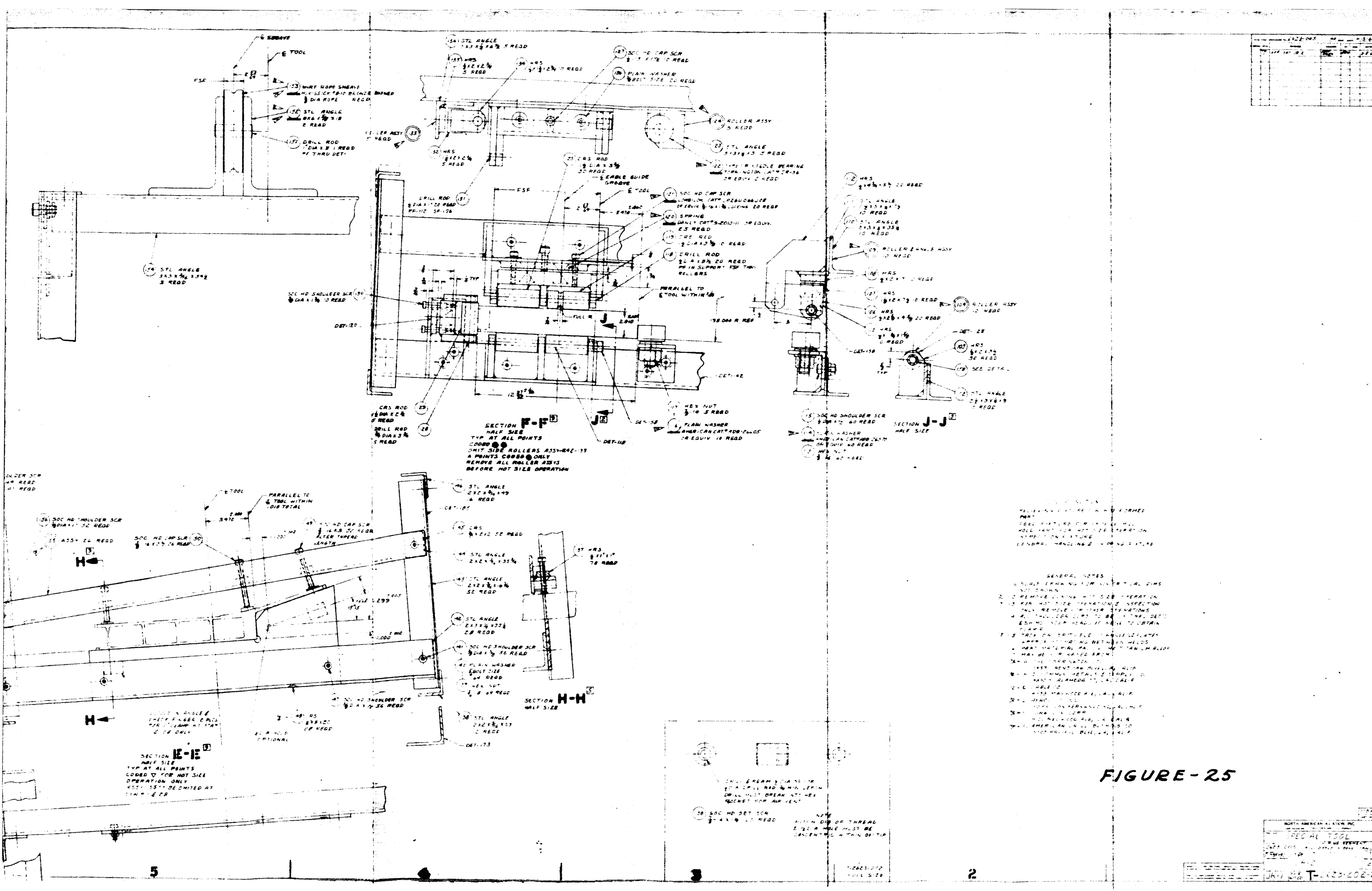


FIGURE-25

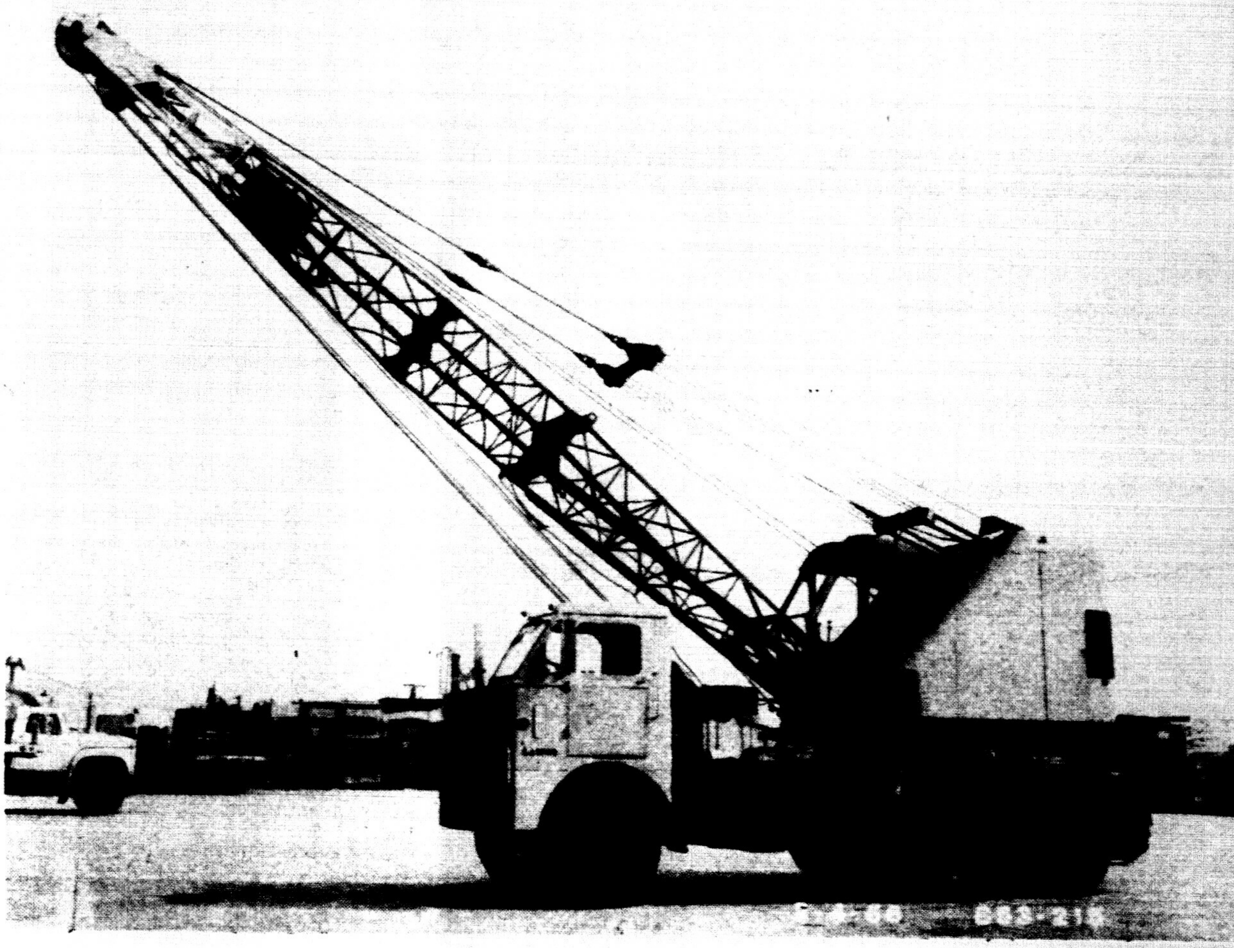


FIGURE 26. 12 TON MOBILE CRANE AT NAA/LAD

INSPECTION

Contour

The 198 inch contour of each formed part will be inspected using a 12 foot template with a 198 inch curvature. Any deviation from this curvature will be measured and submitted in the final report.

Duplex Annealing

After hot contour forming, it is anticipated that a section of the titanium structure will be trimmed for duplex annealing inspection. NASA sharp notch tensile specimens (ST-16) will be used for notch tensile testing of the titanium material.

MACHINE POCKETS

Location

After contouring, one full scale Y-Ring segment will be sent to an outside machine shop for pocket machining. The machining will be accomplished with standard milling equipment and will reduce the overall weight of the pack from 3100 pounds to 1400 pounds.

Transporation

Transportation of the part to the machine shop will be accomplished by North American truck using the receiving and handling fixture, Drawing No. 2623-201-1,-2, to protect the part.

Machining

It is anticipated that the 128 stiffener pockets be machined on a horizontal boring mill. The Y-Ring segment will be mounted so that the plane of the arc is horizontal. This permits support of the overhanging portions of the Y-Ring on an extension of the machine bed. Cutting of the pockets will be in the horizontal direction. Figure (27) shows a developmental pack with the pockets machined.

STEEL TOOLING REMOVAL

Location

The steel tooling will be leached from the full scale part after pocket machining by an outside vendor. The selection of the vendor will be based on past experience and available facilities, as well as price and schedule.

Transportation

Transportation of the part to the selected vendor will be accomplished by North American truck using the receiving and handling fixture, Drawing No. 2623-201-1,-2 to protect the part.

Leaching

The steel tooling encased in the rib-to-skin stiffeners will be removed by chemical leaching with nitric acid. The full scale part, after pocket machining, will have 128 stiffeners with steel encased between the ribs and the skins. The total steel weight to be removed is approximately 900 pounds. Time required depends upon temperature and concentration maintenance, surface area exposed, removal of reaction products from the surface, and passivation reactions. Recirculation of acid is preferred to remove reaction products and to bring active solution in contact with the iron surfaces. A starting nitric acid concentration of approximately 50% at 150°F is anticipated. The temperature will increase with reaction to approximately 200°F.

SURFACE CLEAN-UP

Chem-Milling

The final fabrication operation for the full-scale Y-Ring segment will be the removal of any surface contamination on the titanium resulting from the rolling and hot contour forming operations. This is to be accomplished by chem-milling per NAA/LAD Process Specification LA0103-003; however, an initial grit blast may have to be employed prior to chem-milling to successfully removed the surface scale resulting from the rolling and hot contour forming. Figure (28) shows a completely processed developmental pack.

INSPECTION AND EVALUATION

One Full-Scale Segment

After complete fabrication processing, one full-scale Y-Ring segment will be non-destructively inspected prior to shipment to MSFC. This inspection will include visual, penetrant, dimensional, and as rolled ultrasonic examination. Trim material from this segment will be examined for mechanical, physical, and metallurgical properties.

Evaluation of Sections

The second Y-Ring segment will be cut up in sections for destructive evaluation. This evaluation will include dimensional checks, metallurgical evaluation, mechanical properties, and physical properties. Comparisons of the two Y-Ring segments will be made and a correlation of destructive and non-destructive tests will be made.

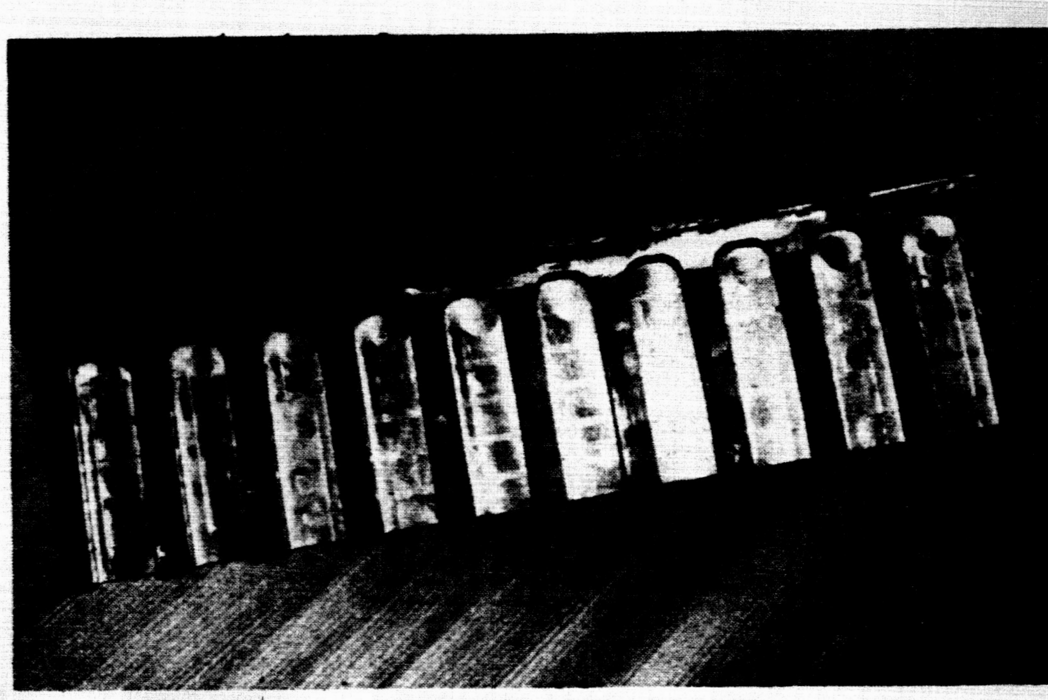


FIGURE 27. DEVELOPMENTAL PACK WITH POCKETS MACHINED

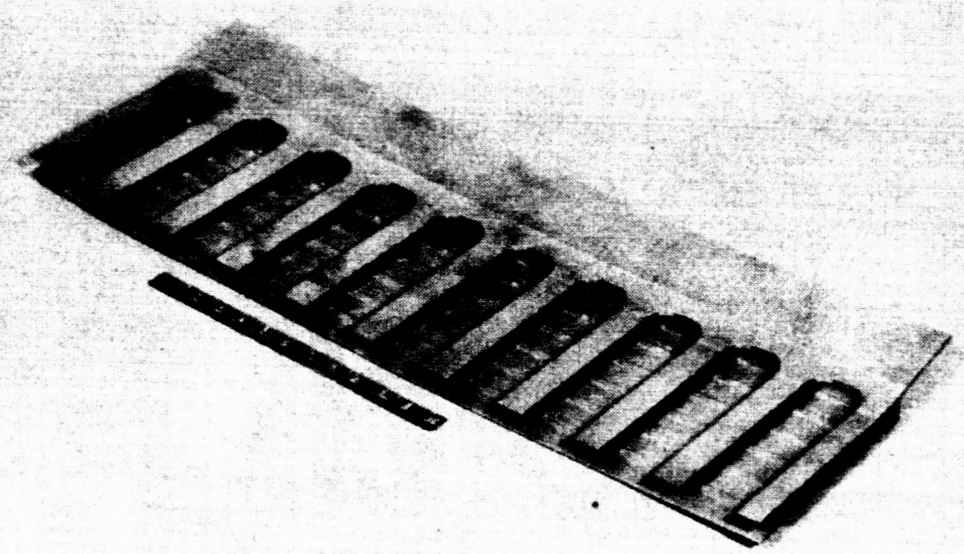


FIGURE 28. COMPLETELY PROCESSED SUB-SCALE Y-RING SEGMENT

SHIPMENT TO MSFC

Shipment of the full-scale Y-Ring to MSFC will conform to the most economical method acceptable to the common carrier, which will assure safe and proper delivery to destination. The handling fixture 2623-202-1,-2 shown in Figure (24) and (25) is anticipated for use as a shipping fixture, and the shipment will be conducted in accordance with Article X in NASA Contract No. NAS8-20533 entitled "Research and Development for Fabricating a Simulated Titanium Alloy Y-Ring Segment for the S-1C Fuel Tank".

INSPECTION AND TEST EVALUATION PROGRAM

A quality assurance program that encompasses all phases of operation for the development of the Y-Ring segments, including in-process, assembly and end item inspection and tests necessary to assure that all materials, equipment and services conform to contract drawings and specification requirements will be maintained prior to delivery to MSFC for acceptance. Figure (29) outlines the inspection and test evaluation program for Phase III.

RAW MATERIAL INSPECTION

Upon receipt of material, the supplier's test reports and certifications will be reviewed for compliance with the Purchase Order and applicable material specification requirements. Upon compliance with the Purchase Order requirements, Procurement Quality Control will ensure visual and dimensional conformance with the applicable procurement specification. The surface finish of the material will be examined for required condition and evidence of discrepant surface imperfections. The length, width, thickness, flatness, and straightness of the material will be determined.

Supplemental testing will be performed to include:

Metallurgical Properties - The microstructure of the material will be evaluated by metallographic examinations. This will include examinations for evidence of surface contamination and for basic microstructure. The depth of the surface skin (oxygen and nitrogen enrichment) will be measured and reported for subsequent process control.

Chemical Analyses - Chemical analyses of each lot of material will be performed to determine the material's conformance with the tensile property requirements of the procurement specification.

The steel raw material will be analysed to determine its chemical identification.

MATERIAL PREPARATION INSPECTION

Subsequent to incoming material tests, the titanium and steel raw stock will be prepared for lay-up. Material preparation includes the mill-polishing and chem-milling the titanium to remove the brittle surface skin (oxygen and nitrogen enrichment) and the machining of detail parts. During mill-polishing, the supplier will be required to measure the material thickness before and after belt grinding of each surface. This will ensure that equal amounts of material is removed from each surface. These measurements will be re-checked by NAA Source Inspection. After mill-polishing, the titanium material will be chem-milled to insure the removal of the enriched skin. The chem-milling will be performed in accordance with Specification LA0103-003. After chem-milling, the

FIGURE

INSPECTION AND TEST EVALUATION PROGRAM OUTLINE

INSPECTION OF INCOMING RAW MATERIAL

- REVIEW OF SUPPLIERS TEST REPORTS
- VISUAL EXAMINATION OF SURFACES
- DIMENSIONAL MEASUREMENTS
- LABORATORY TESTS OF TITANIUM
  - METALLURGICAL PROPERTIES
  - CHEMICAL COMPOSITION
  - TENSILE PROPERTIES
- LABORATORY TESTS OF STEEL
  - CHEMICAL COMPOSITION

INSPECTION DURING MATERIAL PREPARATION

- ASSURANCE OF CONTAMINATION REMOVAL FROM PLATE
- DIMENSIONAL INSPECTION OF MACHINED DETAILS
- SURVEILLANCE OF PROCESSING

PACK LAY-UP INSPECTION

- ASSIGN INSPECTION RECORD BOOK (FOR EACH PACK)
- RECORD DETAIL ACCEPTANCE IN RECORD BOOK
- RECORD PACK DENSITY & SHIM LOCATIONS
- ENSURE CLEANLINESS OF DETAILS
- INSPECTION WELDING
- LEAK CHECK

SURVEILLANCE AT ROLLING MILL

- LEAK CHECK (MA0115-116)
- DEGASSING
- SEALING OF PACK
- TEMPERATURE CONTROL
- REDUCTION
- DIMENSIONS OF PACK AFTER ROLLING

INSPECTION OF ROLLED PRODUCT AS RECEIVED FROM THE ROLLING MILL

- NON-DESTRUCTIVE
  - VISUAL
  - DIMENSION
  - ULTRASONIC
- METALLURGICAL TESTING
  - BOND ADHESION
  - TENSILE
  - CHEMICAL
  - METALLOGRAPHIC

INSPECTION DURING HOT FORMING

- TOOLING INSPECTION
- TOOL PROOF TESTING
- INSPECTION OF MACHINED DIMENSIONS & SURFACES
- ASSURANCE OF CLEAN TOOLING FIXTURES & SEGMENTS
- SURVEILLANCE OF THERMAL OPERATIONS
- CONTOUR INSPECTION
- INSPECTION DURING LEECHING & CHEM-MILLING

FINAL INSPECTION OF SEGMENT DELIVERED TO MSFC

- VISUAL INSPECTION
- PENETRANT INSPECTION
- DIMENSIONAL INSPECTION
- METALLURGICAL TESTING

EVALUATION OF SEGMENT RETAINED BY NAA

- ULTRASONIC INSPECT
- PENETRANT INSPECT
- BOND ADHESION
- TENSILE TEST
- CHEMICAL ANALYSIS
- NOTCHED - UNNOTCHED TENSILE RATIO
- BEND TESTS
- METALLOGRAPHY

plate stock will be checked dimensionally by the supplier and verified by NAA Source Inspection. The machining of the titanium and steel details will be in accordance with Specification LA0103-004 where applicable. After machining, the details will be inspected dimensionally for conformance with drawing requirements.

PACK LAY-UP INSPECTION

Prior to lay-up, each pack will be assigned an Inspection Record Book. See Figure (30) for a typical record book. The specific processes and manufacturing methods utilized during fabrication of each segment will be maintained and recorded in the record book. The dimensional acceptance of the yoke cavity, titanium and steel details; shim dimensions, and their locations will also be recorded in Inspection Record Book. Inspection will ensure that proper cleaning, welding and leak checking techniques used are in accordance with the requirements of applicable specifications.

ROLLING INSPECTION

The rolling mill operations shall be conducted under the surveillance of NAA personnel. These operations will include:

Leak check and de-gassing of pack prior to rolling
Sealing of pack
Temperature control of pack before rolling
Reduction during rolling
Dimensions of pack after rolling

The rolling mill shall submit with each pack the following information: (1) The leak check results and any necessary repairs; (2) A description of the de-gassing cycle; (3) A description of all heating cycles; (4) The rolling temperature and number of reduction cycles; (5) The dimensions of the rolled pack.

AS ROLLED SEGMENT INSPECTION

Nondestructive Testing - Upon receipt of the rolled Y-Ring segments, the rolling data will be reviewed and inserted into the designated Inspection Record Book. The diffusion bonded segments will be visually inspected for surface conditions and dimensionally inspected to drawing requirements. The segments will then be ultrasonically inspected. The results of these tests will be entered in the Inspection Record Book.

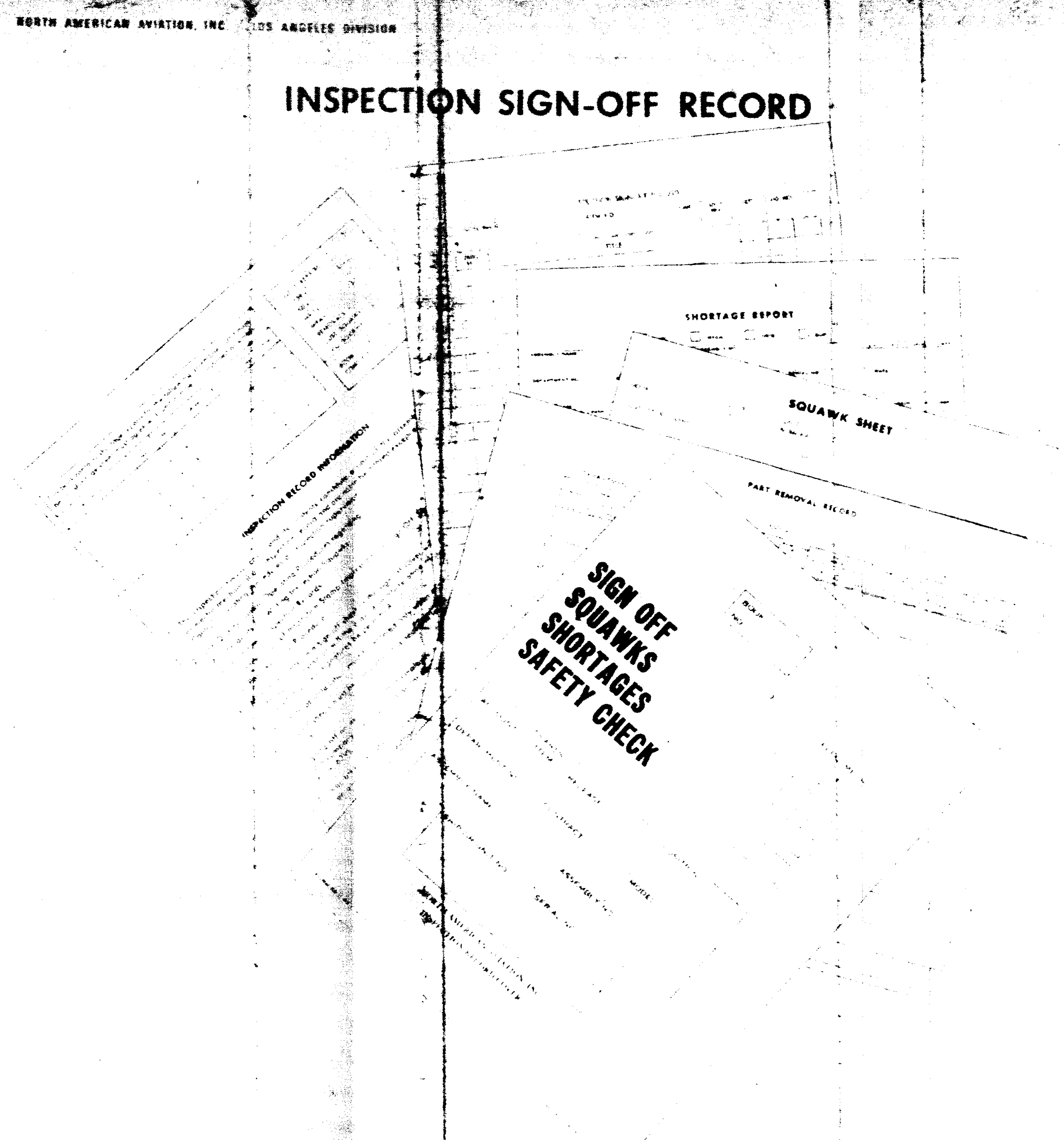


Figure 30 Inspection Sign-off Record (Example)

Metallurgical Testing - Trim material will be cut from each part and metallurgically tested. The microstructure of each segment will be examined for evidence of contamination and core material for basic microstructure. The depth and nature of the surface contamination will be measured and reported.

Chemical analyses will be performed to determine any changes in the chemical composition as a result of the rolling cycles.

Sufficient tensile tests will be performed to determine the tensile properties of the rolled material and the bond strength of representative diffusion bonded joints. Results of these tests will be entered into the Inspection Record Book.

HOT CONTOUR FORMING INSPECTION

Tooling Inspection - Prior to fabrication of the Y-Ring segments, the handling fixture, hot forming die, and the contour template will be inspected for dimensional accuracy and approved prior to their use.

Tool Proof Testing - The temperature uniformity of the dies at processing temperatures will be monitored to prevent localized overheating and deterioration of properties. The capability of the dies and presses will be determined by the placement of sufficient thermocouples in the dies and press platens to measure the temperature uniformity. Temperature surveys will be recorded on approved strip-chart multi-point recorders.

Inspection of Machined Dimensions and Surfaces - All machined dimension will be inspected for conformance to applicable drawing requirements and the machined surfaces to LA0130-004 requirements where applicable.

Assurance of Clean Tooling Fixtures and Segments - The tooling and each segment will be adequately cleaned prior to the application of heat to minimize surface contamination.

Surveillance of Thermal Operations - The hot forming and duplex annealing of the Y-Ring segments will be conducted in accordance with LA0102-003 and LA0111-028 respectively where applicable.

Calibrated thermocouples will be attached to the part and strip-chart recorders will be utilized to assure that all critical time-temperature cycles are met.

Contour Inspection - Subsequent to the duplex anneal cycle, the segments will be inspected for contour with a 1/3 full size check fixture.

Inspection During Leaching and Chem-Milling - Conformance with the applicable requirements will be monitored and verified.

After chem-milling, the surface contamination removal will be checked by measurements, bend tests, visual, and metallographic examinations.

FINAL INSPECTION OF SEGMENT DELIVERED TO MSFC

Visual and Penetrant Inspection - The Y-Ring segment shall be inspected visually and by Penestrip. Penestrip is an NAA invented penetrant test method which detects all surface defects including tight, minute cracks. Therefore, it is applicable to determine bond failures during the hot forming and duplex annealing cycles.

Dimensional Inspection - All critical dimensions, including contour, will be inspected and compared to applicable drawing requirements.

Metallurgical evaluation of Trim Material - Trim material from the segment will be metallurgically tested to determine tensile properties, chemical composition, microstructure of the bonds, and presence of surface contamination.

EVALUATION OF SEGMENT RETAINED BY NAA

Three to five sections, will be processed in the same manner as the segment being delivered to MSFC. The test sections will then be given an ultrasonic and penetrant evaluation.

After nondestructive testing, the sections will be mechanically tested to determine the tensile properties of the various components, the strength of the diffusion bonded joints between the rib and the face sheets, and the notched-unnotched tensile ratio of one of the face sheets. The presence of lack of surface contamination will be determined by bend tests and metallography. Metallographic examinations of the bonds, fillets, and grain structure will be performed. Chemical analysis of the interstitial content of the sections will be obtained. The evaluation tests will be performed in sufficient quantity to verify that the results are representative of the entire segment, but all tests will not necessarily be performed on all sections.